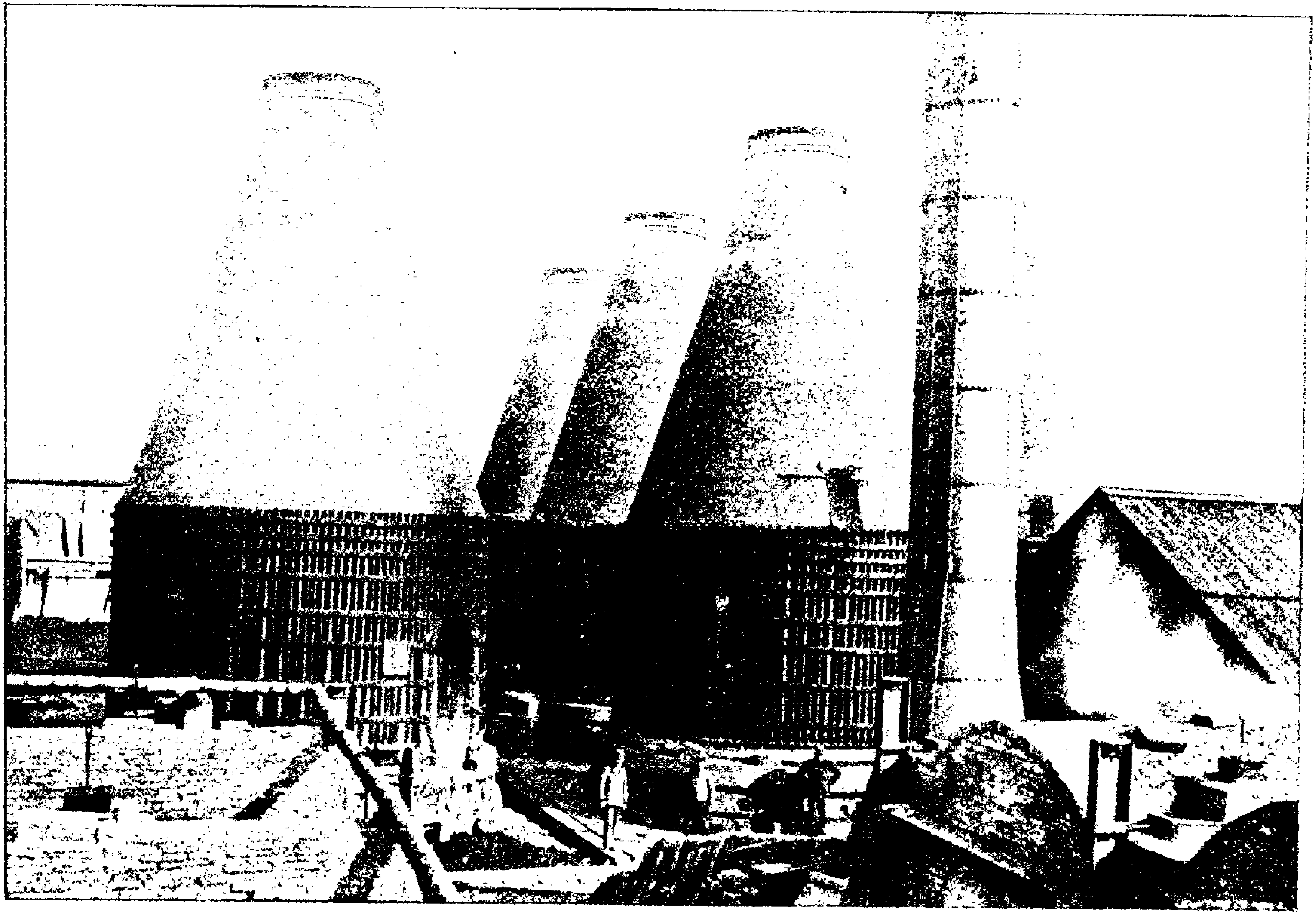

KILNS OF THE PERTH AMBOY TERRA-COTTA COMPANY, PERTH AMBOY, N. J.

(Frontispiece.)

A PRACTICAL TREATISE

ON THE

MANUFACTURE OF

BRICK, TILES AND TERRA-COTTA:

INCLUDING

STIFF-CLAY, DRY-CLAY, HAND-MADE, PRESSED OR FRONT AND ROADWAY PAVING BRICK, ENAMELED-BRICK, WITH GLAZES AND COLORS, FIRE-BRICK, AND BLOCKS, SILICA-BRICK, CARBON-BRICK, GLASS-POTS, RETORTS, ARCHITECTURAL TERRA-COTTA, DRAIN-TILE, GLAZED AND UNGLAZED ROOFING TILE, ART TILE, MOSAICS, AND IMITATION OF INTARSIA, OR INLAID SURFACES;

COMPRISING EVERY PRODUCT OF CLAY EMPLOYED IN

ARCHITECTURE, ENGINEERING, AND THE BLAST FURNACE.

WITH A DETAILED DESCRIPTION OF THE DIFFERENT CLAYS EMPLOYED, THE MOST MODERN MACHINERY, TOOLS, AND KILNS USED, AND THE PROCESSES FOR HANDLING, DISINTEGRATING, TEMPERING, AND MOULDING THE CLAY INTO SHAPE, DRYING, SETTING AND BURNING.

BY

CHARLES THOMAS DAVIS,

THIRD EDITION. REVISED AND IN GREAT PART RE-WRITTEN.

ILLUSTRATED BY TWO HUNDRED AND SIXTY-ONE ENGRAVINGS.

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PREFACE TO THE THIRD EDITION.

THE fact of the sale of two editions of the *Practical Treatise on Brick, Tiles and Terra-Cotta*, coupled with a continued demand for copies after the exhaustion of those editions, may be taken as conclusive evidence of the acceptance which it has met with among the trade, and that other considerable body of persons who are interested in the manufacture and use of brick, tiles and terra cotta.

The United States is rapidly earning a reputation for comfortable homes and beautiful architecture, and brick is the material out of which they are usually constructed and ornamented —for terra cotta is only another name for brick which have been enriched by the hand of the artist. Brick is also the material out of which are built our massive temples of trade and commerce, our magnificent temples of religion, and our palaces of art and learning.

Brick made of suitable clay or shale and thoroughly burned are also rapidly coming into use as the material with which to pave our public roadways, a substance which is cheap and easily repaired and which possesses almost unlimited endurance under even the heaviest traffic.

The chapters on Clay, Tempered-clay Brick, Fire-Brick, Enameled-Brick, Street Paving Brick, Pressed Brick, Terra-Cotta, and Roofing-Tile have been entirely rewritten, and every other portion of the volume has had such thorough re-

vision as to bring it up to the present advanced state of the various branches of the Clay Industry.

In its new and improved shape it is with much confidence believed that it must, in the present and the future, even more than in the past, commend itself to and be useful to those for whom it has been specially prepared.

CHARLES THOMAS DAVIS.

WASHINGTON, D. C.
605 Seventh Street, May 15, 1895.

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MANUFACTURE OF BRICK, TILES, AND TERRA-COTTA.

CHAPTER I.

THE HISTORY OF BRICK.

THERE is little doubt that clay, in combination with such materials as would bind it together in a compact mass, was employed in the structure of the primitive human dwelling. In course of time this method of construction was superseded by the use of the same plastic substance, moulded either with or without other ingredients into suitable forms, which were afterward dried or burned—the result being the production of the article known as "brick."

In the words of Bishop Berkeley: "Westward the course of empire takes its way," and in order to trace the history of Art we must backward follow its course to the far East, to the dreary delta of the Nile, and there, among the mounds of the arid wastes which cover the palaces of kings, the monuments of an extinct faith and the graves of dead nations, trace so far as we can its early history and development.

In Egypt the art of pottery is credited to the inventive genius of the gods. It is to Num, the oldest of created beings, that the earliest practice of the potter's art is attributed, and it is this god who is credited with having moulded the human race on his potter's wheel; the heavens and the earth, the air, the mountains, hills and streams, had previously been made by Num, who then suspended the sun and moon between the earth and the heavens, and after having made man, whom he formed out of the black Nilotic clay, he then breathed into his nostrils

the breath of life. This attribution of the invention of the art of pottery to the gods is unequivocal corroborative proof of the statement that this art was employed prior to the historical period.

Brick have been employed from the earliest times in the execution of many undertakings of grandeur and magnitude. A complete history of brickmaking would be analogous to that of civilization with its advances and declines, for the authentic record of this branch of pottery is older than that of any other ceramic production, extending through forty-one centuries; the descendants of the sons of Noah, who journeyed from the East and located on the plains of Shinar, being the first potters of whom we have positive attestation.

In our own times structures of great altitude have been projected; but the Washington Monument and similar undertakings appear insignificant when compared to the stupendous conceptions of those bold men, who, in 2247 B. C., said: "Go to, let us make brick, and burn them thoroughly." And they said: "Go to, let us build us a city and a tower, whose top may reach unto heaven." *

The story of the manner in which this proposed monopoly of that portion of space between earth and heaven was defeated by confusion of the tongues of the builders, is too familiar for repetition here. But that something was accomplished will appear from the speech of Moses to the Israelites, delivered seven hundred and ninety-six years later, in which cities in the land of Canaan are referred to as being great and walled up to heaven.†

In tracing development in the art of brick-making we find that progress has often been slow and uncertain; it has flourished in ages of prosperity with other arts, and like them it has been lost in ages of darkness; but as with them it awoke with the Renaissance, and is steadily improving with the progress of time and the spread of knowledge.

Machinery is doing much to lighten labor, but in all ages the

* Genesis xi. 3, 4.

† Deut. i. 28.

work required to make brick has been of the hardest kind, and many have been faint with toil in their production, in modern as well as in ancient times.

My observation leads me to say that the old manual method of brick-making has destroyed many a man in the prime of life, and has undermined the constitutions and wrecked the systems of the most robust natures.

The children of Israel, as early as 1706 B. C., were made to serve the Egyptians with rigor, and their lives were made bitter with hard bondage in mortar and in brick; and Pharaoh, in 1491 B. C., in order to increase the burdens and labor of the Israelites, commanded the task-masters, saying, "Ye shall no more give the people straw to make brick, as heretofore; let them go and gather straw for themselves, and the tale of the bricks, which they did make heretofore, ye shall lay upon them."*

Pictures illustrating the above passages are still preserved on tombs in Thebes, in which some of the laborers are represented carrying water in large pots to temper the clay; others carry on their shoulders large masses of clay to the moulder, while others still are bearing off the brick, and laying them out on the ground to dry, the dried brick being carried in yokes suspended from the shoulders of bowed and weary laborers. Task-masters, who were personally responsible for the labor of their gangs, are plentifully represented, observing that there was no shirking of the labor or slighting of the work.

Rameses II. of the Egyptians, who is the same as the great Sesostris of the Greeks and the Pharaoh of the Old Testament, reappears as a mummy before the world to-day. The pride which carried him in conquest over half the eastern world, the dignity that enabled him for many years to support the weight of empire, the hardness of heart that made him so severe a task-master to the Hebrews, and the unyielding obstinacy that made him do prolonged battle with the chosen servants of God, are all visibly stamped upon his countenance now, as when

* Exodus, v. 7, 8.

Moses stood before him vainly pleading that he would "let the people go." How much better it would be for those who oppress the people to lift their heavy hands while still alive than to stand either in cerecloth or in history, as Rameses does, an immortal monument of injustice, tyranny, and wrong.

The mud of the Nile is the only material in Egypt suitable for brick-making; the modern plan is the same as the old; a bed is made into which are thrown large quantities of cut straw, mud and water, and this is tramped into pug, removed in lumps, and shaped in moulds, or by the hands. The moulded clay is sun-dried, not burned, the brick of Egypt, both ancient and modern, being adobes.

Herodotus testifies that the walls of Babylon were built of brick made from the clay thrown from the trenches surrounding the place. Accounts of the extraordinary mounds of brick at Birs Nimrod, the supposed site of Babylon, and the remains of other ancient cities of the stoneless plains of the Euphrates and Tigris, have been given by noted Eastern travelers. The buried palaces of Nebuchadnezzar have, for a long series of years, provided brick for all the buildings in the neighborhood; there being scarcely a house in Hillar, a city of over 8,000 inhabitants, built close to the ruins of ancient Babylon, which is not almost entirely built with them. "To this day," says Layard, "there are men who have no other trade than that of gathering brick from this vast heap, and taking them for sale to neighboring towns and villages, and even to Bagdad." Many brick found in this ruin are coated with a thick enamel or glaze. The colors have resisted the effects of time, and present their original brightness.

On every brick that was made during the reign of Nebuchadnezzar it was his custom to have his name stamped, and Sir Henry Rawlinson, the Oriental scholar, in examining the brick in the walls of the modern city of Bagdad, on the borders of the Tigris, discovered on each brick the clear traces of that royal signature.

The Babylonish brick were usually of three colors: red,

pale-yellow, and blue, and also in all ancient Egyptian decorations the primary colors, red, yellow, and blue, were principally employed; green was the only secondary, to which were added black and white. The profuse employment of colored decoration is the distinctive feature of Babylonish architecture, the brick being stamped out of a mould, and impressed with cuneiform inscriptions, which is a certain form of writing, the component parts of which may be said to resemble either a wedge, the barb of an arrow, or a nail, the inscription being placed in a sunken rectangular panel. The sizes of the Babylonish brick vary, the burned ones being thirteen inches square and three inches thick; the adobes or sun-dried brick measuring from six to sixteen inches square, and from two to seven inches thick. The adobes were laid in clay, the work being striped horizontally, every four or five feet in height, with thick layers of reed matting steeped in bitumen to form the bond; the burned brick were laid while warm in hot bitumen, the bond being formed in the laying. In addition to the above kinds there were triangular brick for corners of walls, and wedge-shaped brick for arches, which were sometimes concave below and convex on top.

Recent excavations have been made on the site of the Pithom, the treasure city built by King Rameses II. with the bondage-labor of the children of Israel. The buildings prove to have consisted almost entirely of tremendous store-houses built of adobes. Some of these sun-dried brick were made with straw and some without it.

The pyramids of Aboo Roash, Dashour, Howara, and Illahoon, were constructed of adobes; unburnt brick have also been found in the joints near the foundation of the third pyramid of Gizeh. The bricks in the pyramid at Aboo Roash contain no straw, and those in the pyramid at Saqqara contain only a small quantity of straw on the outside. The northern pyramid at Dashour was built of brick about sixteen inches long, three inches wide, and four and three-quarters inches thick. The southern pyramid at Dashour is constructed of

brick fifteen and one-quarter inches long by seven and three-quarter inches in width and five and one-half inches in thickness, or thirteen and one-half inches long, six and one-half inches wide, and four and one-half inches in thickness, and these brick contain a large quantity of straw. The brick used in the construction of the pyramid of Howara measure seventeen and one-half inches in length, eight and three-eighths inches in width, five and one-eighth inches in thickness, and like the brick used in the southern pyramid at Dashour, they contain a large quantity of straw.

The Fayoom and the Delta, which contain vast quantities of rich alluvial mud, and which are remote from the principal quarries, undoubtedly presented, at the most ancient period of Egyptian history, the appearance of an enormous brick field. The mud brought down by the Nile was particularly suitable for the manufacture of brick and pottery.

Like the valley of the Nile, the plains of Assyria were abundantly supplied with clay by inundations of the Tigris and Euphrates, and the material was largely employed for the manufacture of brick, which were easily moulded from the common clay tempered with water and mixed with stubble in small quantities to bind the mass together. The formation of the high artificial platforms or mounds on which the Assyrian city edifices were erected was the chief employment for brick. These platforms were usually about twenty feet high, and the clay for the manufacture of the brick was excavated from the trench or dry ditch by which the city was surrounded. But in addition to this employment they were also used in enormous quantities for the walls of the city, and also for the construction of the edifices of the citizens and the burial-places of the dead. The brick were probably made in a square wooden mould of the proper depth, and some of them are impressed with marks somewhat resembling the Egyptian. The Assyrian adobe brick are not so carefully and regularly made as those of Egypt and Babylon, and there is great difficulty in accurately measuring them. The Assyrians employed burned brick prin-

cipally in positions where it was desirable to keep out moisture, and in addition to being used for ground-floors and outer-walls of the palaces, they were also employed for the construction of some tombs.

The unburned brick are called, in hieroglyphs, *teba*, which is the same word as the one used for a chest or box, and the term probably originated from the shallow wooden box or mould in which they were shaped and afterwards turned out. It is thought that the business of brickmaking was a royal monopoly in Egypt, as a very large number of brick are found in that country with prænomens and names of monarchs, Thothmes I. and III., Amenophis II., Thothmes II., and Amenophis III., of the Eighteenth dynasty; of Rameses II., of the Nineteenth, of the High Priests of Amen Ra, named Pthameri, Parennefer, and Ruma, etc.

No brick appears to have been impressed before the Eighteenth dynasty, nor later than the Twenty-first. Thothmes III. is believed to be the prince who reigned at the time of the Exodus of the Hebrews. The brick made during the reign of this prince are impressed with his cartouche, which is an oval, on which the hieroglyphic characters used for his name are stamped, and adobes made in his time were 12 inches long, 9 inches wide, and 6⅜ inches thick, and one in the British Museum weighs 37 pounds and 10 ounces.

It is probable that the brick bearing the names of kings were intended to be used in the construction of public works.

It is not probable that, in either Assyria or Chaldea, any restrictions were imposed as to the length of time which the brick should be dried before being used, and this statement is corroborated by the evidence of M. Place, who excavated numerous shafts through the massive Assyrian buildings for the purpose of exploration, and from these shafts it was possible to form an idea of the condition in which the brick had been laid in the walls. The sides of these exploring shafts showed a uniform surface without any evidence of joints. It has been supposed by some that the crude brick were first dried in the

sun, and then before being used were dampened with water before being laid; but this supposition is repudiated by Place, who explains that, should the brick have been laid in that manner, each joint would be marked and made more distinguishable by rather darker tints than the remaining portions of the wall, but there is in reality no such discoloration. The fact that the horizontal portions are often distinguishable from each other by their differences of tint proves that the excavations of Place were made through brick, and not through a mass of earth solidly compressed by employing the rammer.

It is not possible that sun-dried brick ever become sufficiently hard not to be destroyed by the action of water. The walls of Matinea were thrown down by Agesipolis, King of Sparta, who turned the water of the Ophia along the base of the walls of unburnt brick. The walls of Eion, on the Strymon, were attacked in the same manner by Cimon, son of Miltiades.

Unburnt brick were never regarded by the inhabitants of Mesopotamia as a safe building material, and experience demonstrated the necessity of supplementing with huge buttresses the buildings in which the material was employed, and it is probable from the evidence of those who have explored these ruins that the supplemental supports were more thoroughly and carefully constructed than the buildings, the walls of which they were intended to sustain. The crude brick walls of Chaldean buildings were perforated with numerous ventilating tunnels, through which the warm air could penetrate, and thus dissipate any moisture that might be contained in the brick. Perforations of this kind have been discovered in the ruins of Babylon and also in other Chaldean cities; but in Assyria no such openings of the kind which we have described for the admission of air have been found. It is the almost unanimous opinion of explorers that sun-dried brick were never left unprotected in Mesopotamia, the material being commonly protected by a thin coat of stucco. It is stated by M. Place, that at Nineveh this stucco was formed by a mixture of burned chalk and plaster, the compound producing a sort of white gum, which adhered

intimately to the clay wall. It is probable that many buildings had no outward ornament beyond that imparted by the brilliant whiteness of this stucco, the effect of which is still to be seen even at the present time in the whitewashed houses of the East.

The great perfection to which the ancients carried the art of brick-making is probably due to the abundance of labor, plenty of time to devote to each stage of the work, their great patience and painstaking, and the natural drying and preserving climate of the East. The dry, warm atmospheres of Egypt, Assyria and Babylonia, which countries were the nurseries of the ceramic arts, have kept in a good state of preservation for more than three thousand years the sun-dried brick so common in those countries; many well-preservad adobes are also found in towns and walls of ancient India.

Brick, burned and unburned, were employed in the construction of the Great Wall of China, which is the most remarkable fortification ever erected by human hands; millions of men were employed for the space of ten years in its construction, and it was completed in 211 B. C. The length was about 1250 miles, the height averaging about 22 feet; each face of the wall was built of hewn stone or brick, and filled in between with earth; it was wider at the bottom than at the top, which was sufficiently wide for six horsemen to ride abreast; it was built by the great Emperor of China, Shee-Hoang-Ti, who is the national hero.

In Spain the use of sun-dried brick has more or less continued in some portions even to the present day. In Mexico, sun-dried brick have been continuously employed for many centuries, and the early Spanish-American buildings in California were commonly constructed of adobes. The exterior walls of the buildings in Mexico and the Spanish-American buildings in California were often covered with a bluish stucco or enamel, which was sometimes applied after the erection of a building or sometimes before. In the southern portion of Texas, adobes are still often used for the construction of dwellings. In the southern portion of the State of Kansas, which is

often visited with wind storms which destroy frame structures, adobes are often employed for buildings; the walls are commonly carried up to the height of one story, and the roof has a steep pitch and extends about two feet six inches beyond the faces of the walls. The steep roofs give a half story or attic in the upper portion of the dwelling, and the wide projecting eaves protect the walls. The adobes are made about eighteen inches square and four inches thick, and half brick to correspond. These sun-dried brick, as were those of old, are sometimes made with straw and sometimes without. Buildings constructed of adobes are termed, in the Western States, "dobies," and in Mexico, Texas, Colorado, New Mexico, and Arizona, buildings so constructed are called "adobe houses."

It is probable that burned clay did not find great favor with the ancient Greeks, as they possessed an abundance of stone.

The walls of Athens, on the side towards Mount Hymettus, were built of brick, and this is probably the largest undertaking in which they were employed by the Greeks.

The use of brick for architectural construction was never, at any period, extensive in Greece, but in some few cases they were employed in minor public edifices. Their first application has been attributed to Hyperbius, of Crete, and Euryalus or Ayrolas. The brick were made with a mould, and were named after the number of palms' lengths.

In the first century of the Christian era, while the brick made by the Romans were of a superior quality, those made by the Greeks were very inferior.

But little is known of the material used in the early buildings of the Latin cities; yet, judging from the great extent and destructiveness of the fires in Rome, it is inferred that wood entered largely into the construction of buildings up to the time of Nero. During his reign, in A. D. 64, two-thirds of the city was destroyed by fire. Augustus, who devoted so much time and thought to beautifying Rome, had restricted the height of buildings to seventy feet, but this height was still further curtailed by Nero after the conflagration, and in the re-

building a certain portion of the houses were constructed of a fire-proof stone from Gabii and Alba.

With the conquest of Carthage, Greece, and Egypt, the Romans became acquainted with the arts of those subjugated countries, and tried to improve upon and use them for the embellishment of the imperial city, and it was most likely their innate desire for improvement that led to the burning of brick in kilns.

Although burnt brick were used in the tower of Babel, and to face the adobes used in the building of the walls and palaces of Babylon, it is probable that the credit of first burning brick in kilns belongs to the Romans; but it is hard to fix the time when this improvement took place.

Layers of thin brick, separating the tufa surface into panels, called *opus reticulatum*, were used in the time of Augustus. In the time of Nero the walls were faced entirely with excellent brick-work, called *opus lateritium*.

Pliny says that the brick made in Greece at this time were very inferior, and not fit to be used in the construction of a Roman dwelling, and that no party-wall was allowed to be more than eighteen inches in thickness, and that the material would not support one story.

The brick must have been of a very poor quality, or else Pliny greatly misjudged their strength, for at the present time many buildings are being constructed four or five stories high, with the party-walls for most of the way only nine inches in thickness, of the poorest kind of "salmon" brick, from which the water has barely been driven out by the action of the heat; and if Pliny could see some of the brick now used he would quake for the safety of the occupants of some modern hotels, apartment-houses, office-buildings, and dwellings that have recently been erected for speculative purposes in London and some portions of this country.

In the first century of the Christian era the brick were better than at other periods; they were large, flat, and thin, generally two feet square and one inch thick, and were what we call

Roman tiles, but were used for building walls, and not merely for roofing or pavements; the facing brick were triangular, the broad side being outwards. But brick gradually became thicker and shorter, until in the fourth century they were very often as many as four to a foot on the face of the wall, which is about the same as in modern structures.

The Romans did not build their walls entirely of brick; they were used only as a facing or veneering, the same as we use front or pressed brick, the remainder or backing of a wall being of concrete, and thus we find that a large number of the great Roman buildings are constructed of concrete, faced with brick.

The brick-work of the first two centuries of the Christian era, the crowning period of art in Rome, was superior to any other. In the third century there was barely a perceptible change, but in the fourth there was a most decided deterioration, and brick-work went back with the times, old material being re-used extensively, as in the arch of Constantine.

Knowledge of the art of brick-making has probably at no time become entirely extinct in the East, but after the fourth century, in sympathy with the decline of all other arts, and the dying Roman civilization, the knowledge of this art gradually expired, and was lost to Western Europe.

The Romans made brick extensively in Germany and England, and though it might seem strange that such an art, when once acquired, should have been lost, nevertheless the remains of buildings between the Roman times and the thirteenth century show no evidence of brick having been made in England. In a few instances only were they re-used as old material from buildings left by the Romans, as at Colchester and St. Alban's Abbey—the old Roman town of Verulamium, near which the latter is situated, supplying material for it.

The buildings of the Anglo-Saxons were usually of wood, rarely of stone until the eleventh century, and it is not improbable that the primitive English churches may be among the earliest stone buildings of Western Europe, after the time of the Romans. In these buildings the arches are generally plain,

but sometimes they are worked with rude but massive mouldings. Some arches are constructed of brick, all of them taken from some Roman building, as at Bixworth, or sometimes stones are employed, and these usually have a course of brick or thin stones laid upon the top of the arch, as at Britford church, Wiltshire.

It has been thought that brick were made in England, under the direction of Alfred the Great, as early as A. D. 886, and it is possible that, in rebuilding London and other cities which had been destroyed by the Danes, brick were used; but this is not probable, as there are but few buildings in any part of Western Europe now in existence that are earlier than the eleventh century, and if brick were made in the time of Alfred, in England, there are none at present in existence, and no authentic history of any building erected in his reign in which they are said to have been used, and it is most probable that the earliest true modern or Flemish brick building existing in England is Little Wenham Hall, in Suffolk, which was erected in A. D. 1260.

In the reign of Henry VI. brick construction was not general, Hurstmonceaux Castle, Sussex, built early in his reign, being one of the principal brick buildings of that period; but under Henry VIII. and Elizabeth the manufacture of brick flourished, and they were used mostly for large buildings, the smaller ones being of timber construction, in which small panels of ornamental brickwork were sometimes formed and exposed between the upright studs.

Only a few instances of early fourteenth century brick-work occur, and they are towards the close of the style; but in the fifteenth century brickwork became common, and we have in the Lollards' Tower, of Lambeth Palace, built in A. D. 1454, and the Manor House, or older portion of Hampton Court Palace, Middlesex, built in A. D. 1514, good examples of the English brick architecture in mediæval times. The ecclesiastical and palatial architecture of Italy of this period is rich in many beautiful specimens of brick-work, and in addition to the

employment of colored decorative brick-work, the most elaborate mouldings and ornamentation in terra-cotta and brick are exhibited.

Until the first quarter of the seventeenth century, the brick made in England were of many different sizes, but by Charles I., in A. D. 1625, their size was regulated and made nearly uniform.

After the great fire of London in September, A. D. 1666, brick was the material universally used in the reconstruction, and ornaments carved with the chisel were introduced into some of the brick-work erected towards the last of that century in that city.

In A. D. 1784, brick were subjected to taxation by George III., which burden was not repealed until A. D. 1850; the tax for this time, two-thirds of a century, averaging about 4*s.* 7*d.* per thousand for common brick, and about 10*s.* per thousand for the finer grades.

The material of which a town is built depends generally upon the geology of the surrounding district; as in a mountainous country, like Scotland, cities of stone, such as Edinburgh, Glasgow, and Aberdeen, naturally abound; but London and most of the great cities of England, being situated in alluvial valleys and plains, are built of brick made from the alluvial clay beneath and around them. In Holland and the other provinces of the Netherlands, where no stone except a very soft and inferior sandstone is found, the use of brick as the chief building material became almost universal from earliest times, even the paving of the streets and other public works being done with brick. There are buildings in some cities of the Netherlands in which stone has been largely used, but they are the exception rather than the rule.

Peter Mortier, in a small book published in A. D. 1782, gives a description of the city hall of Amsterdam. He says that the old city hall was erected earlier than A. D. 1400, that the front and sides rested on divers stone columns, and that on one side there was a four-square stone steeple; that the building was

burned July 7, A. D. 1682, and the heat was so great that everything was consumed except a piece of brick-work in the steeple. The new building was constructed on the site of the old one, but was commenced in 1684, part of the old structure having been taken down to make room for the new. In order to obtain a foundation for the new building, 13,659 piles were driven, upon which were placed seven feet of brick-work to form the foundation.

It was under Wouter Van Twiller, of Amsterdam, a governor appointed by the Dutch West India Company, that the first brick buildings were erected in this country. In 1633, soon after his arrival on Manhattan Island, Governor Van Twiller erected for his own use a substantial brick house, which was the most elaborate private dwelling which had up to that time been attempted in America, and during the remainder of the Dutch dynasty this dwelling served for the residence of the successive chiefs of the colony. He also built several small brick dwellings for the officers, which, with his own, were erected within the walls of the fort. The brick used in these buildings were brought from Amsterdam, and were of such a good quality that but few were broken in the long and rough voyage. The Dutch seem to have succeeded well in making a strong and very durable quality of brick, which brick have been famous from an early period for soundness, and specimens of them brought over by the early settlers from Holland are yet to be met with in some of the old Dutch houses of New York.

Among the Puritan emigrants to New England money was very scarce, and, under Winthrop, carpenters and bricklayers, whose services were in great demand, and had a monopoly price, were forbidden to accept over 12*d.*, and afterwards, in 1630, 2*s.* per day, the penalty being 10*s.* to giver and taker. The bricklayers were also the stone-masons; they ranked under the first head, but a much larger amount of building was done in wood and in stone than in brick in those times.

The earliest settlement in this country in which brickmakers are recorded as being part of the population was the colony of

New Haven. In this industrious and inventive little company it is probable that the first brick made in this country were burned in 1650. They had no rich backers willing to foot the bills for costly brick buildings, as the Dutch West India Company had done for Governor Van Twiller in his building operations at Manhattan, or New Amsterdam, as it was called at a later period. They had made several attempts to produce brick at earlier times, but had failed, and it is not probable that the very few which they did succeed in burning were of a very superior quality. But, like the building of their ship, which sailed from their ice-bound shore and was never again heard of, though faulty in many respects, their production was an evidence of great energy, and it is the inheritance of this same quality that has made all that section of country a great manufacturing and inventive district.

The Virginia colonists possessed clay of a far superior quality for brick-making; but they do not seem to have made any attempt to utilize it. A few brick were brought from England and used in the furnaces of an iron foundry and a glass-house, both of which were destroyed during the great massacre of March, 1622, and appear to have comprised the entire manufactures of the colony.

Brick has been a choice material for building purposes in the State of Pennsylvania from its primitive days. In a letter from William Penn to his agent, J. Harrison, as Pennsbury, written in 1685, in speaking of a lady who had purchased land and intended to emigrate, he said: "She wants a house of brick, like Hannah Psalter's, in Burlington, and she will give £40 sterling in money and as much more in goods. It must have four rooms below, about 18x36 feet large, the rooms 9 feet high, and two stories height." Some idea of the great purchasing power of money in those days, as well as the price and value of buildings, can be seen from the above.

In 1705 the price of bricklayer's labor in Philadelphia was 3*s.* 6*d.* per day, and the price of brick 22*s.* per thousand. One of the oldest public buildings in this country constructed of

brick was the old court-house in the city of Philadelphia, commenced in the fall of 1705, and to these Pilgrim Fathers the erection of this building was a great undertaking and their largest endeavor. Gifts, fines, assessments, and forfeitures were all combined to give it the amplitude of a "Great Towne House" or "Guild Hall," as it was sometimes called when first built. To modern ideas this building was small and ignoble; but in those days it was grand and imposing in the eyes of all the populace. The total expense of the structure was £616, the brick costing 29*s*. 6*d*. per thousand, and the bricklaying costing 14*s*. per thousand. This primitive building was erected in the middle of High, or as it is now called, Market Street, at the corner of Second, and after being used for various purposes for one hundred and thirty years, it was demolished in the spring of 1837. For about twenty-eight years it was used as a court-house; but its use for that purpose was superseded by the erection of "the new State-House," or "Independence Hall," as it is now called, which was built of brick, in 1733. Another primitive brick building in that city was the "Great Meeting-house" of Friends, at the south of the "Great Towne House," on the corner of Second and High streets. This building and the surrounding brick walls which inclosed it were erected in 1695, the ground being given for that purpose by George Fox, for "truth's and Friends' sake." Early in 1719 brick came into use for foot pavements in Philadelphia, and the great demand for them made the material very expensive.

Brick do not appear to have been much used in the early buildings of Boston, as wood seems to have been the favorite material for building purposes with the Puritan emigrants, stone being sometimes employed. The first "Towne House" erected in Boston was constructed of wood; it was built about 1657, and stood at the head of State street, and was consumed in the great fire of 1711. Its successor was a brick edifice, erected in 1712, on the same spot, which in turn was destroyed in the fire of 1747. The "old State-House" was built the next year, 1748, and as late as 1791 it was described as "an elegant brick

building, 110 feet in length and 38 in breadth." The first Episcopal church in Boston was erected in 1689, of wood, at a cost of £284, and was at the corner of Tremont and School streets. The "Triangular Warehouse," which stood at the head of the "Towne dock," was one of the earliest brick buildings erected in Boston; it was built by London merchants about 1700. Its foundation was of stone and its walls of brick, which were of a larger size than the brick of the country in later times.

Brick-work became common in this country in the early part of the eighteenth century, and until the trouble between the colonies and the mother country, brick were imported mostly from England. There was not much inducement to produce home-made brick previous to this time, as vessels sailing with light cargoes for the colonies would finish out with brick, which commanded ready sales at moderate prices, rather than with stone ballast, which would have to be thrown overboard before receiving their heavy return cargoes of tobacco and other exports of the colonies.

In this way a number of brick buildings were constructed on the tide waters of the Atlantic coast, in the times which preceded the troublesome period of the Revolution. At the time immediately following this war, there was but little done in the line of building; the generally distressed condition of the industries and the finances of the country was a bar to any improvements except such as were in the nature of repairs necessary to make buildings habitable.

The condition of things after the adoption of the Constitution gradually changed: churches and other buildings of a public character, which had remained in an unfinished state during the entire period of the war, were completed, and a few houses of a substantial character were erected in some portions of the country, home-made brick being generally employed when they could be obtained, and the character of the buildings admitted, which was but seldom, as wood and stone entered largely into the construction of the great proportion of all buildings.

The inventive genius of the new nation was not much stimulated to improving on the manner of the mother country in the production of brick. In fact, those which we then made were poorly moulded and burned, and compared unfavorably with the common building brick of English and Dutch manufacture. But at the present time, both for quantity and quality, we have no equal in any nation of the world, and for this we are largely indebted to the American patent system, which greatly fosters and encourages development in this line, as in other and kindred arts.

Improvements in modes or machines for manufacturing common brick received but little attention until about 1835; previously they were more remarkable for being unique in some special point, of but small importance, than for any generally good achievements; that is, no attention was paid to the resulting brick after it came from the kiln; the whole idea seemed to be to shape or mould it in some manner. For instance, one machine was made like a box now used by plasterers to run off their lime; it was elevated slightly, and the mud, which was mixed in the box, allowed to pass through a grate into a large framework having sides about three inches high, and divided by wires stretched lengthwise and across it, which lay upon the bottom, and when the clay in the shallow box was somewhat hardened, the wires were raised and the brick thereby cut and formed into shape. The box, when emptied of the clay, could be easily moved on wheels running on a plank gangway to the next shallow mould-box, and so on. But the slush stock made in this way was very inferior; it would dry unequally, be full of cracks, and was subjected to no packing as in the pug-mill, or pressure as by machines of to-day, or a blow as is done by the hand-moulder, who dashes the tempered and packed clay into the mould with great force, and again drives it down and closer together with the hands and plane. When the brick came from the kiln they were light, very open or porous, therefore absorbed water readily, and were entirely unfit for building purposes.

The mode of manufacturing brick has been revolutionized during the past twenty years, and it seems almost like a miracle when we note the present development of this art and then recall that the first crude brick machine which was made in this country was invented in 1835 by Nathaniel Adams, who died at Cornwall, N. Y. The machine was simply a hand-moulder; but he afterwards, about 1840, invented a power machine. It proved quite successful, and a few of them are still in use. Mr. Adams was also the first to invent and use the iron tempering-wheel. The model of his brick machine may still be seen in the patent office at our National Capital. It is related that in the 40's, Mr. Adams undertook to establish a brickyard at Philadelphia, and built a power (horse-power, we presume) machine, but he was not allowed to start it, as a mob destroyed the machine and drove Mr. Adams and his family from the city. They took refuge in Camden, where they remained two weeks or more, until the workmen had quieted down and it was safe for them to return. In the year 1840, many of the people in Philadelphia could not get work at any price, and they did not like to recognize anything which they thought would take the physical labor out of their own hands. From such beginnings has our business grown, until now (1895) there are annually consumed in the leading cities of this country the following mentioned enormous quantities of brick:

New York	1,100,000,000
Chicago	600,000,000
Philadelphia	450,000,000
Boston	175,000,000
St. Louis	225,000,000
Washington	150,000,000
Omaha	100,000,000
Cincinnati	100,000,000
Cleveland	100,000,000
Pittsburgh	100,000,000
Total	3,100,000,000

Brick-making in the South, and especially in the States of

Texas, Louisiana, Mississippi and Florida, and also in California, Oregon, and Washington, has within the past ten years not compared favorably with other sections of our country, the reason being mainly owing to the railroads developing immense tracts of the very choicest timber lands, thereby encouraging the establishment of a large number of saw-mills, thus affording not only a lighter and cheaper building material for the great masses, but one also better adapted for the climate. But this tendency to frame construction is liable at any time to cause enormous loss from fire, as disastrous conflagrations are likely to occur at any moment either in New Orleans or San Francisco, and similar cities in which lumber is so extensively used as a building material.

The enlarged and more convenient methods of making brick, as practised in the vicinity of the larger cities of the United States, came from necessity to meet the increased demand, owing to the growing of our building interests incident to the increase of our population. With the increased demand for building material in the eastern and northern portion of the country came a decrease in our lumber supply. Something had to be found to take the place of timber, and nothing could be so serviceable and durable as brick, or that would withstand the action of the elements so well.

During the past twenty-five years there has been created a demand for road-way paving brick. These brick differ from building brick in many particulars. The best of them do not absorb more than one per cent. of moisture, and are very hard —turning even a steel drill. Over 300 cities and towns have adopted this form of paving, which is a guarantee of its success.

The most popular kind of paving brick at present is the so-called vitrified brick, made of some grade of shale. These are good paving material, and it is not the intention to say anything to their discredit; but it must be granted by their friends and advocates, that they are not the only brick that make good pavements. Those who have studied the history of brick pavements the most, know too well that the first pavements laid.

and those that gave brick their present popularity as a material for street pavements, were not made of shale, and in fact many of them were not very well vitrified, yet they have stood the test of nearly a quarter of a century, and are in excellent condition to-day. With this fact patent to all, the present fashion runs after the shale brick, and in many instances engineers insert in their specifications the requirement that the brick used in paving the streets of their cities shall be of this class. The motive that prompts this is laudable, and the engineers doubtless insert it in all sincerity; but is it always wise and for the best that they should do so? Their desire is to get the best pavement that is to be had, and fashion says that brick made of shale make the best.

An old saying declares that, "Enough is as good as a feast." In the face of prejudice and inexperience, the early brick pavements have wrung from the minds of the people the confession that they are good enough.

Upon this basis the present boom in brick pavements has been built. Is it not then not only an injustice, an ingratitude, but an exhibition of arrogance, for the shale brick to claim that it alone is adapted to the work of street paving? If it should happen, as it often does, that there were no factories working shale near the city to be paved, but good paving brick made of other clays could be obtained near and at less expense than those made of shale, it would not be right to specify that only brick made of shale should be used. The engineer who did this and required his patrons to bear the additional expense would not be a faithful servant who guarded the people's interests. All of this goes to show that the market for paving brick is so largely in the hands of interested parties as to make it an objectionable feature of the business.

The use of brick for street pavements has only come into general use within the last decade. The universal prosperity of the country during that time has made it possible to pave the streets of many towns that heretofore had been neglected. Since the desirability of brick for this purpose has been estab-

lished and they have been placed upon the market at prices that made it possible to improve the much needed but long neglected streets, an impetus has been given to the business that is almost without a parallel in the annals of the industries.

During the present decade there have been two classes of streets to pave, those that had been neglected during the growth of the cities for many years past, because of the want of a suitable material for the work at prices within the means of the cities needing pavements, and those that result from the growth of the towns during the decade.

There has been an attempt made to bring the work of paving up to the times, and to complete the work according to the needs of each city. This work is being rapidly carried forward, and whenever it is accomplished there will be a decline in the amount of paving done each year, and this amount will naturally become adjusted to the growth of the country.

For further information on the subject of paving brick manufacture, see Chapter VI.

Some of the hardest and most durable brick which have probably ever been produced in the world, the writer saw made in a few hours and in a peculiar manner at El Paso, Texas, in November, 1887, and the process consisted simply of running the slag as it came from the smelting furnaces into moulds in which they were formed into brick. The adoption of this plan for utilizing slag would serve a two-fold purpose, and it would do away with the necessity of finding vacant ground for the constantly increasing accumulations of this material, and also be a source of profit to the smelter, as the brick manufactured would be indestructible, hard as steel, and finely finished.

The business of manufacturing brick, like any other calling, demands, in the present age of machinery and competition, the closest attention and personal supervision, even to details, in order to insure success; and the measure of prosperity is small to the brick-maker whose heart is not in, and whose mind is not upon his business. In this craft there is no sentiment; on the contrary, the brick-maker's life is one of laborious applica-

tion, unremitting watchfulness, with large and constantly increasing responsibilities. From the moment the clay is dug in the bank to the time the brick is delivered to the building, there is not a single step or move but which demands the individual supervision and exacts the watchful eye and constant care of the brick-maker who expects and desires success. Before long the old-time typical brick-yard, with its primitive outfit, will become a tradition of the past, and will have scarcely a place in our memories. It has answered the purpose for which it was designed, has performed its part in the building and improvement of this marvellous land. In the earlier struggles of the people of this country to provide shelter and homes for their families, it has filled no unimportant place. Up to within a few years the hand-brickmaker did not recognize the logic of wants, or yield to the restless genius of the minds engaged in the persistent purpose of inventing machinery that would make a better brick cheaper than could be made by manual process. We cannot blame him if he still loves the sound of the walk dropping in the mould, the peculiar smell of the poplar slider, and the cracking of the pen-mouth fire, all of which have a charm for the old-time hand-brickmaker.

The brick-machines which will be hereafter enumerated have indeed revolutionized the craft in almost every particular. With every mechanical device which is to be described in this volume I am perfectly familiar, and have seen all in actual operation, and for this reason have selected such for illustrating the different portions of this work. There are other contrivances and machines made in this country and in Europe, that may be equally as good as some herein given, and no effort will be made to praise those which shall be used for illustrations above others which may have equal claims for consideration. The thousands of inventions cannot all be mentioned; and rather than fall into a sea of error, so common in mechanical descriptions, I shall be compelled to select only those the merits or demerits of which I can discuss from personal knowledge.

Before any attempt is made to explain the processes or machines employed in the manufacture of brick or the other branches of pottery, it is highly important that there should be a thorough knowledge of the character of clay, and some of its changes while under the several conditions to which it is to be subjected. This will be attempted in a general way for brick in the following chapter.

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CHAPTER II.

CLAY.

BUILDING BRICK CLAYS; HUDSON RIVER CLAYS; PAVING BRICK CLAYS; FIRE-CLAYS; METHOD OF ANALYSIS FOR FIRE-CLAYS, FELDSPARS, KAOLIN, AND FIRE SANDS; TERRA-COTTA CLAYS; KAOLIN OR CHINA CLAY.

UNDER the general term *clay* many varieties are included which are more or less used in the arts and manufactures. The characteristic property of clay, and one possessed by no other mineral substance, is that peculiar condition known as plastic. The ingredient of clays to which this feature is due is a hydrous silicate of alumina. When pure it is of a snow-white color; to the touch it has a soft unctuous feeling, and is very easily broken; it adheres to the tongue and gives off a singular smell when breathed upon, which has been designated the argillaceous odor. When moistened with water a considerable quantity of the fluid is absorbed, and upon manipulation the clay speedily passes into the plastic condition, which enables it to be molded into many different forms.

The purest clay found in nature is known by the technical name of kaolin, or China clay.

The word "Clay" is derived from the Anglo-Saxon Claeg; Dutch, Klei; German, Kleben, which means "to stick."

In addition to sand, there are also compounds present in clays which often have an important bearing in determining their economic value. Among these are iron pyrites, sulphate of lime, carbonate of lime, dolomite, carbonaceous and bituminous matter, oxide of iron, etc. To these are due the various colors which characterize ordinary clays, and which vary in their effect upon the material when it is applied to technical purposes. In geological works clays are divided, in accordance with their

occurrence, into primary and secondary deposits. From their physical conditions of structure and chemical composition, clays are technically separated into various classes, expressed by the words fat, long, lean, short, plastic, argyllites, clay-slates, marls and loams.

From chemical and mechanical considerations it is evident that the major portion of the insoluble residue left after the decomposition of feldspathic rocks cannot be pure kaolin, but must necessarily be a mechanical mixture of it, with more or less partly altered feldspar and the most easily decomposed materials of the original rock, with a certain proportion of quartz. This material in the past has been deposited in the depressions on the earth's surface, and in changes due to the unstable condition of the earth's crust was subjected to heat and pressure and became consolidated, forming a true rock. This, in turn, was upheaved by the internal forces of the earth, and was again subjected to disintegrating influences.

Among the materials forming clay are various minerals containing protoxide of iron; these, under atmospheric action, become altered to higher states of oxidation, and give to the clays all shades of color from the finest yellow to the deepest brown; they also explain why pure white kaolin is so seldom found. This disintegration of the primitive rocks and the rocks that were formed from them, going on through millions of years, has resulted in a deposition in nature's settling tanks of vast amounts of clay of more or less purity. They occur in beds of varying thickness, and follow the stratification in dips and strike of the underlying rock. These primary deposits of clay have been rearranged many times by subsequent geological changes, which have had effect in redispositions of these clays, and sometimes resulted in the purification of the clay mineral proper, and at other times in its degeneration.

The power to pass, with water, into a dough-like plastic state, decreases in proportion as a sandy element is mixed with the clay. It is strongest in the "fat" and weakest in the "lean" clays. A "fat" clay dries very slowly and unevenly;

and the molded objects will warp and crack in drying. Aron found that the "linear shrinkage" does not correspond with the drying of the clay, as might be expected, but ceases when followed up to a certain point, which he designates as the "limits of shrinkage." The water evaporated up to this point, he terms the "water of shrinkage;" the remainder of the water lost, until the weight of the sample remains constant at a temperature of 266 degrees F., he calls the "water of pores;" the sum of both is total water.

If we assume that the minute particles of clay substance possess the round shape claimed by Dr. Koenig, this behavior is easily explained, as the "water of shrinkage" envelops these particles, and upon evaporation will allow them to approach, until each touches the other at six points on the surface. The intervals between all other points will still be filled with "water of the pores;" and its evaporation cannot produce any shrinkage of the clay. Now, Dr. Koenig claims that it is an important rule for the potter that the number and sizes of the pores are independent of the water contained in the clay, and is constant for all plastic clays; and, further, that the cubical shrinkage is equal to the volume of water lost by evaporation up to the limit of "linear shrinkage." Aron contends, further, that if the purest clay is mixed with fine quartz sand, the shrinkage will increase up to a certain point, which he terms the "point of greatest density." From this point the shrinkage decreases again, with increasing leanness, while the porousness increases. On submitting clay to a red heat, two molecules of water are driven off from the silica of alumina at that temperature, and, as a result, the clay shrinks a second time. This is known as the "fire shrinkage," and can be neutralized by the addition of finely-divided sand, and may even be made to produce a slight expansion. Finely pulverized chalk is also an excellent material to counteract the "fire shrinkage" in clays.

The ordinary yellow brick clays contain iron in the state of oxide and carbonate chemically combined with water, forming what are known in chemistry as hydrates. The expulsion of

this water in the process of burning imparts a red color, due to the conversion of the hydrated oxides of iron into the anhydrous form. The principal constituent in brick clay, and that upon which its plasticity depends, is the chemical combination of silica and alumina, more particularly described under the head of "Kaolin." This constituent used alone shrinks and cracks in drying, warps and becomes very hard when baked. Silica is also present in nearly all clays in an uncombined state, such as sand. A proper proportion of sand prevents cracking, shrinkage and warping, and furnishes silica necessary for a partial fusion of the materials which increases the strength of the brick. The sand also makes the brick more shapely and equable in texture; but an excess of sand in clay renders the brick made from it too brittle. A small quantity of carbonate of lime has a beneficial effect upon brick clay in two ways—it lessens the contraction of the newly-made brick in drying, and acts as a flux in the kiln by the formation of silicate of lime, which binds the particles together. It is evident from this that an excess of carbonate of lime in the clay would cause the brick to melt and lose its shape. Iron pyrites in a brick clay are objectionable; also the presence of carbonaceous matter to any considerable extent, as a black discoloration, similar to that produced in brick in proximity to chimney flues, is likely to occur.

Common salt is nearly always present in minute quantities in clay. In that near the seashore the amount is apt to be so great that brick made from it are certain to be of a poor quality. Salt melts readily and glazes the outside of the brick, and the heat cannot be raised or maintained sufficiently long to burn them to the core, or into good hard brick; as a consequence they are soft, and from the presence of the decomposed salts of magnesia and soda, are always damp, owing to the tendency of these salts to absorb moisture from the atmosphere. The presence of the alkaline carbonates in clay to any notable extent, prevents its being used as a brick clay, the alkali causing the material to melt readily.

Rare minerals containing such metals as cobalt, copper, zinc, and such salts as phosphate of iron, are met in clays, but are exceptions and are of no importance in practical work. Thus it appears that mineralogically, clays are kaolinite, mixed with sand, colored by iron and organic matter, and showing varying amounts of feldspar, mica, and other silicates and titanates. The chemical investigation of a clay should endeavor to present these facts, besides grouping those bodies together which are similar in action and effect.

BUILDING BRICK CLAYS.

Brick-makers divide clays into three classes:

First. Plastic or strong clays, which are chiefly a silicate of alumina, which are by the workmen called "foul clays:" a more fitting name, and one by which they are also called, is "pure clay."

Second. Loams and mild clays are those in which there is a considerable proportion of sand intermixed.

Third. Marls or calcareous clays are, as their name indicates, clays containing a notable quantity of carbonate of lime.

"Malm" is the name applied by English brick-makers to an artificial marl, made by adding to and intermixing with the clay a proper proportion of carbonate of lime.

As a general rule, a clay fit for the manufacture of a first-class quality of building-brick is not met with in nature. There is almost always a deficiency of sand and lime. A good brick clay is one that contains sufficient fusible elements to bind the mass together, but not so much as to make the brick adhere to each other or become vitrified. Such clays contain from 20 to 30 per cent. alumina, and 50 to 60 per cent. silica, the remainder consisting principally of carbonates of lime and magnesia, and oxide of iron.

Pure or "foul clays" are sometimes used for brick without any admixture of substances to improve the material. Brick thus made are generally deficient in weathering qualities. The color of brick depends upon the composition of the clay, the

character of the added ingredients, the temperature at which they are burnt, and the amount of air admitted to the kiln. A clay free from iron will burn white, but as a general rule carbonate of lime (in the form of chalk) is added to produce white brick. The presence of iron oxides produces a tint which varies from light yellow to dark red, the intensity of color increasing with the greater quantity of the oxide. If 8 or 10 per cent. of iron oxide is present, and the brick becomes intensely heated, the red oxide of iron combines with the silica and fuses, producing a dark-blue or purple color. The presence also of a small quantity of oxide of manganese, in addition to the oxide of iron, will cause a material darkening of the red tint. By the presence of small quantities of lime the red color of iron oxide is modified to a cream tint, while larger quantities make a brown color. Magnesia also changes the red tint to yellow.

In the clays from which the famous Milwaukee cream-colored brick are made, the proportion of lime and magnesia runs up to twenty-three per cent. carbonate of lime, and seventeen per cent. carbonate of magnesia, with nearly five per cent. of iron. The average brick-clays of the drift show from three to ten per cent. of lime, and in these uses it is a valuable agent, but it would be quite fatal to any of the higher uses of clay. The alkalies, *i. e.*, potash, soda and lithia, are found in all clays to greater or less extent, though not all together by any means. Potash is most common and most detrimental, lithia is most infrequent and in the smallest amounts. Its presence has not heretofore been noticed as an element in Ohio clays, but once detected, it was found in a number of samples. Mention has been made of mica and feldspar as the probable sources of the alkalies in clays, and this theory is strengthened from the fact that the largest source of lithia at present is one of the minerals of the mica group, viz., lepidolite.

The knowledge of the composition and properties of clay now current among the clay manufacturers, is almost wholly practical, and there may seem to be ground for surprise that such excellent results should have been obtained with so little

aid from science, but it is to be remembered that much less has been done for this subject than for parallel industries. The scientific research directed to it is much more scanty in proportion to the interest involved than in almost any similar field. What work has already been done has proved very valuable, and further study cannot but be productive of good.

Clay, as we have seen from the foregoing description, instead of being a mineral formed by the ordinary processes of chemical synthesis, is the result of decomposition of granite rocks, or by a closer definition, is the result of the decomposition of feldspars or those rocks which yield them, notably granitic and gniessic rock. Orthoclase, the feldspar from which the body of our clays is derived, is a double silicate of potash and alumina; the other feldspars found accompanying it are albite, or the soda feldspar, and oligoclase, the soda-lime feldspar; these latter forms are in small proportion compared to orthoclase. Ordinary aqueous and atmospheric agencies are sufficient to decompose feldspar, giving rise to hydrated silicate of alumina or kaolin and a soluble salt of potash, which is carried away by the water which accompanies decomposition. Feldspar beds are fruitful sources of the finest kaolins and china clays, and are rarely found without some kaolin accompanying.

The mineral elements in granite and gneiss, as is familiar to all, are quartz, feldspar and mica. The first mineral is not affected by air or water, but the feldspars, and to some small extent the micas, are attacked by the atmosphere. When the feldspar decomposes, the bond which holds the other elements together is gone, and the quartz and mica are carried off by water or mixed with the clay in varying proportions, as the conditions of formation vary. The more the water carries off the purer the clay left behind.

The irregularity of composition which is so characteristic of clay, is thus seen to be the result of the differing mechanical conditions which surround the clay as it forms; it is distinctively a mineral in which other forces than chemical affinity have left their mark; and another element of uncertainty is

added in the fact that if the mechanical conditions were constant, clays would vary with the parent rock, which has no fixed structure.

Thus is exposed, in the origin of clay, the reason of that irregularity which has so long baffled or retarded progress in its study, but which once understood, proves the key to all that follows.

The qualifications for a clay for building brick are simple, viz.: Plasticity when wet, and solidity and hardness when burned.

Clays containing a large amount of carbonaceous matter naturally mixed with it are very objectionable, as brick when made from such clays will, when wetted in the wall, pass out soluble compounds, which discolor the walls, whether they are painted or not, and plastering or stucco-work is discolored by them the same as when brick which have once been used in the inside of a chimney flue and become blackened, are re-used in new work.

It would be useless to attempt decorative work of any description upon brick walls, the materials of which contain a large amount of carbonaceous matter, or if the brick be made from the alluvial mud of the embouchures of rivers, as no possible precaution can prevent the entire destruction of the work.

Carbonate of lime, diffused limestone and lime pebbles, when they are present in brick clays, are a decided hindrance to the production of even a passable quality of building brick, for in the kiln the limestone and lime-pebbles are converted into caustic lime, and when the brick are used below ground, or for exposed walls, the moisture and carbonic acid, which penetrate to every part of a brick, slack the nodules of lime, the swelling causing the brick to burst and break to pieces. Should such brick be used for "filling in," or inside or unexposed walls, the dampness from the mortar used in laying them, and also that contained in the plastering, would, by producing the same bursting and breaking, destroy the finished face of the inside walls.

These are some of the evils which result from the badly-made brick so freely used in Chicago, and arise from the large amount of lime-pebbles in the clay, and the neglect of finely pulverizing or thoroughly sifting the clay, which can easily be done by machinery, at but a small additional cost.

Selecting Clays for Various Kinds of Building-Brick. Brick of uniform quality can be made from low grade clays, but good, salable, uniform building-brick require that suitable clay shall be used in their manufacture; the better the grade of brick produced the more remunerative the price which they command in the market. If common mud-brick are to be manufactured by the hand method of moulding and without the use of machinery for crushing the clay preparatory to pugging, a clay should be selected that is very tender and easily soaked and pugged. The pugging qualities of clays can be determined by digging and pugging a small pit full of the material. The plasticity, as well as the moulding and drying qualities of clays, can also be readily tested on a similar small scale. There is no better way for determining the color to which a clay will burn than by making and burning the brick in a test kiln, such as several of the leading brick machinery manufacturers of the country maintain for testing purposes at their factories. Clays manufactured into a few brick and sent to a neighboring kiln to be burned and tested for color often turn out unsatisfactorily, for the reason that different clays burned in the same kiln tend to impart a uniform color to each other.

If the brick are to be manufactured by the soft-clay process almost any kind of material can be used that will hold its shape in drying. Clays such as the Hudson river clays, which are largely impregnated with quicksand will not retain their shape in drying if they are too much pugged, hence the brick-machines used in the Hudson river district do not have too great a pugging power for the clays.

Both the stiff-clay and dry-press brick machines require for their successful operation a strong plastic clay. Fine front or pressed-brick require clays having all the qualities necessary

for good common brick and in addition the color-producing qualities. Iron is generally supposed to be the all-important constituent necessary to produce a good red color, but there are a number of things and conditions, besides the iron, that are necessary for the successful manufacture of the best classes of salable front brick.

The iron should be equally distributed throughout the mass to be burned. The lack of ability to do this successfully has caused many attempts at artificial coloring of clays to prove failures. The clays must be of such a nature as will enable them to stand sufficient heat, without warping and twisting, to bring out the color. They should also be without those elements which, when brought to a high temperature, unite with the iron and carry it out of the brick and kiln in the form of vapor. An analysis which shows a good per cent. of iron in clay does not always prove that the brick will burn a good red color.

Clays which shrink a great deal are not the best for front-brick making, as they are liable to warp and crack in burning.

Such clays are more liable to show stripes and brown edges than those that shrink less.

In erecting works for the manufacture of building-brick, it is necessary first to determine whether the clay located upon the property is suitable, not only in its nature, but in the quantity present. The digging of one or two pits will not determine the question. Examinations should be made by boring into the earth in a large number of places. This is an expeditious and general method, and it is possible by boring to penetrate all the strata or beds of clay on the property. Large-size boulders cannot be thus penetrated, and layers of gravel are also hard to penetrate, while wet sand, such as quick sand, also offers impediments; these obstacles, however, are usually of no great extent, and by making different trials can almost always be avoided. There are a variety of augers and bits used in making explorations of clay by boring.

The specimens of clay brought to the surface by the boring-

auger are usually fair specimens, disclosing as they do, not only the character, but the thickness of the strata from which they are taken. Of course the number of borings to be made will be governed somewhat by the information obtained from the clays brought to the surfaces. If the strata seems to be of almost uniform depth and thickness, a less number of borings will be required than when less uniformity of the clay formations is shown to exist.

HUDSON RIVER BRICK CLAYS.

The deposits of brick clay extend along both sides of the Hudson river more or less continuously from Sing Sing to Albany, N. Y.

There are isolated patches below the former locality but they are not of any great extent. There are two narrow portions of the river from Staatsburgh to New Hamburgh, and from Cornwall to Jones' Point, where little clay is found.

The embankment in which the clay lies often rises steeply from the shore and the terrace which the clay underlies extends in some cases, especially along the upper portions of the river, one or more miles from the shore, while at other localities is not over 400 to 500 feet wide. In speaking of the terrace extending back several miles, it is not meant in an unbroken stretch, for numerous ridges of rock project above its surface at many localities.

The thickness of the clays is also very variable, they being underlain by irregular ridges of rock, and rounded hills of stratified drift or kames, or as at Verplanck and Cruger's, the clay lies in basins scooped out in the rock by the ice.

On the average, the clay is of good quality, and capable of producing a good brick. The Croton Point clays, and portions of those below Peekskill are very "fat." By a fat clay is meant one possessing great plasticity and being quite pure. Again, at other localities, as New Winsdor and Haverstraw, the clay contains numerous patches of quicksand. These patches are generally flat and lie parallel to the clay layers.

There is hardly a clay-bank, however, which does not show streaks of quicksand.

Two kinds of clay are found along the river, the blue and the yellow; the former always underlies the latter, and occasionally they shade into each other or are interstratified.

As to the relative qualities of the two, the blue makes a better brick, and does not shrink so much in drying and burning as the yellow. The yellow gives a better colored brick, is tougher than the blue, does not occur in as great quantity and is not as plastic. At some yards only the yellow is used; at others, only the blue.

The Hudson river clays are, with few exceptions, situated so as to afford the greatest ease and economy of working. The yards are mostly located along the river front, the clay bank being adjacent to them, and at a higher level, so that the haulage of the clay is down grade to the tempering pits.

Though occurring usuallly in terraces, still the presence of a terrace does not always indicate clay. For instance, at Haverstraw the clay is obtained from the sixty feet terrace, while the 100 feet one is composed of glacial drift and delta material. In prospecting for clay along the Hudson river there is little difficulty in detecting its presence. It can generally be seen on the face of the terrace escarpment, in road-cuttings, or in the sides of gullies made by small streams, which drain the terrace. In some cases the surface consists of sand or gravel, and then has to be pierced by the auger in order to determine the presence and the thickness of the clay. In determing the extent and thickness at any particular locality, it is of importance to make a number of borings, as sometimes the clay suddenly thins out. When the terrace is narrow the clay usually thins out as it recedes from the river. Unfortunately, as far as ascertainable, few borings have been made in these clays to determine their thickness, and in most cases they have not been mined below the level of the yard, which is generally eight to ten feet above mean tide.

PAVING-BRICK CLAYS.

The problem to be solved in the production of street-paving-brick is principally that of compounding clays, or of selecting clays with a special view to manufacturing tough vitrified brick.

In a large number of localities in the United States there are shale clays which are by nature specially adapted to the manufacture of vitrified brick for street-paving purposes. But all localities in which a market exists for such brick, and where it is desired to make the brick for roadway paving, are not so favored, and in such places the question of the proper selection and mixture of materials as will result in producing a hard, tough, street-paving brick is the all-important one.

It is not possible to make good brick for roadway paving from any and all kinds of brick earth. Dirt and clay mixed, and mixtures of sand and fire-clay, and fire-clay and ordinary building-brick clays will not make satisfactory paving-brick. Mr. J. H. Calkins, of Galesburg, Ill., in speaking of this subject, says: "The result of trying to make pavers out of poor clay will be a failure. To make good pavers you want to select a clay which, by giving it a hard burn, will melt together like iron, so that not a particle of water can soak into it, and which can not be even marred by a steel drill. When you have found such a clay, thoroughly pulverize it, make a stiff mixture with water, and mould your brick on a machine with an end pressure. Get all the clay into the brick that you possibly can do; dry as other brick, only give them a harder burn."

Mr. W. A. Eudaly, Cincinnati, Ohio, says: "The idea of using a number one fire-clay for paving-brick is a mistake. What I mean by a number one fire-clay is such as Mount Savage clay, or what we in the West compare to a Mount Savage clay. Such clays are of no use for paving-brick. They will not vitrify, and when burned have no strength; will not stand the frost, but crumble and fall to pieces with the action of frost and wear. A low grade of fire-clay, however, will make an excellent paving-brick, for the reason that it will stand a high degree of heat in burning, and yet can be vitrified, and

is usually strong and tough when well burned. Most low grades of fire-clay possess this quality of toughness, hence the idea that fire-clay must be used for paving-brick. You can often get paving-brick by mixing number one fire-clay with common clay, providing the latter will also stand a high degree of heat in burning. You run the risk, however, of making a brittle brick, as you are likely to burn the life out of the common clay before the fire-clay has been affected by the heat."

Mr. F. E. Frey, Willoughby, Ohio, in this connection says: "I have some experience in the mixing and manipulation of different clays for the manufacture of street-paving-brick. I have seen it done at Columbus, Ohio, where they have a shale clay like fire-clay. By itself it will not make a good brick, but by mixing it with sand and a kind of red clay having iron in it, it makes a good paving-brick. In fact, it makes an artificial flint, and by the time it is burned it is the same as flint, as you cannot break it. You can readily cut glass with it. It makes a fine material for paving purposes by proper manipulation with different clays. In that way you can make a good paving brick when otherwise perhaps you can not."

Mr. Shea, of Decatur, Ill., who has had a large experience in manufacturing street paving-brick from common clay, and who has succeeded in producing a hard, tough, flinty brick, gives his ideas on the subject in the following language: "I admit you must have an intense heat to make a paving-brick, but it is not necessary to have anything pertaining to fire-clay. The further away you can go from fire-clay, in my opinion, the better brick you will have. The clay that will make paving-brick is not as scarce as one might imagine. There is a great deal of paving-brick clay all over the country, and it will be discovered as the demand for paving-brick arises."

Mr. W. D. Gates, of Chicago, Ill.: "Do not give up your clays too quickly; do not make up your mind too quickly that you cannot make paving-brick. It may be that just the little item of tempering the brick in the kiln may change failure to success. A man that has clay that does not fuse easily, that

stands a high heat, no matter whether it is fire-clay or not, has a fruitful field for experiment before him."

Mr. A. O. Jones, of Zanesville, O.: "The majority of good building-brick clays with different treatments will make fairly good paving-brick for light travel. But to stand the wear and traffic of large cities, and to equal granite and other high-priced and expensive pavements, there must be a careful selection of clays, such as semi-fire-clays or some of the shale clays that will stand a high degree of heat so as to become thoroughly vitrified, and at the same time have the toughness that is necessary to stand the continuous friction of heavy-loaded teams from and to the freight stations and wharves.

"We have on our property a 36-foot vein of potters' clay, or clay of the semi-fire clay nature. Owing to the ability of this clay to stand intense firing, we commenced mixing it with a variety of clays which we have, the idea being to secure such a mixture of materials as would result in the production of a thoroughly vitrified brick, suitable in every way for the paving of public roadways. After a variety of experiments, we finally secured a mixture of clays which under intense heat made a paving-brick of great strength and toughness."

Mr. George S. Tiffany, of Tecumseh, Mich., in speaking of the manufacture of vitrified street paving-brick, said: "I could tell you the best way to make vitrified brick, but the question at the root of the matter is: What clay will make the best paving brick? I can only answer that question by saying that the clay must be ascertained by experiment and trial. The differences in clays are just as infinite as the characters of men. Of fire-clays there are a vast number of varieties, some of which clays possess scarcely any refractory power. There are clays that are called common clays that are superior in refractory power to some clays that are called fire-clays. A clay that will make good sewer pipe is good clay from which to make vitrified brick. In the process of vitrification, you want to stop just before the process is completed. At that point it is liable to go into the molten state and your whole kiln come down

upon your hands. You must ascertain by the most careful experiments, if you attempt to make vitrified paving-brick, how high you can set your brick, or else you will endanger your whole kiln and lose thousands of dollars by foolish trials.

"There are many of our surface clays that are simply decomposed shale which has become plastic clay under atmospheric action. Such clays take the salt-glaze as a general thing best. They have the proper elements, containing sufficient silica and iron, and they are free from infusorial earth, lime, etc. Take a clay that will rapidly effervesce under the action of acids, and you cannot get any kind of a glaze upon it, and I suggest the acid test to you before you make any other experiments. You can also judge something by observation of the effect of fire upon your own kilns of brick, whether you have any prospect of making paving-brick. If the heads of your arches—if the under brick, the key brick are glazed, that is an encouraging sign. There was a friend of mine asked me not long since to visit his yard. He wanted to talk with me about putting in a stiff-mud machine to make paving-brick. I went to see him. Of course I wanted to see his kilns and his clays, especially his clays. I went out to the yard and we examined the burned brick in the kiln. They were removing the brick and he took out a brick from the arch and showed it to me. One end of that brick was burned to a good hard heat with no sign of vitrification whatever.

"The other end of that brick was burned and shriveled out of shape. Now, there was not a point between the two ends that had the elements of a vitrified brick that was in a fit condition as a body for a paving-brick. There are a thousand such cases all over the country. It is absurd for any one to attempt to make paving-brick from clays of that kind."

Brick for roadway paving, as will be seen by the foregoing description of the clay to be used in their manufacture, are entirely different from common brick. Clay for such brick should be able, without fusing, to withstand a sufficient degree of heat and for a long time, to render the brick hard and impervious to water.

Lime, magnesia and the alkalies in the clay render it fusible, and they are to be avoided: iron, beyond 6 to 10 per cent., if the clay is silicious, also renders it fusible. Silica and alumina constitute the refractory parts of brick, and the other parts named, the fluxing part.

From the experience of the leading manufactures of paving-brick, it is concluded that fineness of grain is most essential. When fine-grained clay has a hard, compact structure, no pains should be spread to reduce it in a dry state to an impalpable powder.

When the clay is neither dry nor fine, but of desired composition, it may be calcined and then finely ground.

The clay used at Galesburg, Ill., is of a shale formation and is known as soapstone. It lies near the surface of the hills, and varies in depth from fifty to nearly three hundred feet. It is almost free from grit, and when pulverized and moistened it is sticky or doughy in the fingers. A lump taken fresh from the bank without crushing or drying takes water very slowly, and if rubbed on a smooth surface before drying will present a slick, glassy or oily surface.

The Diamond Brick Company, of Kansas City, Mo., exploits a clay similar to the clays above described, except that it is found at a depth of from fifty to two hundred feet below the surface, and is therefore mined by driving entries and drifts the same as coal is mined. The texture of this clay is very fine. It is almost free from grit, and can be polished with a smooth surface when taken fresh from the bank. In the green state, or fresh from the bank, it is darker than that found at Galesburg.

The clay at Atchison, Kan., is also classed among the soapstone clays, and is very similar to the three above-mentioned, except that it runs from a light gray to a dark gray in the bank. It also has a slight trace of sand or grit, and does not polish quite so smooth when green. It vitrifies at a high degree of heat, and stands up well under fire.

At Sioux City, Iowa, the clay is also found in very high bluffs. Viewed from a distance, it resembles more the appear-

ance of large or thick layers of stone than either of the former clays. The physicial appearance of these clays is different from all other clays that we have seen. In its natural state it is very hard and dense. Has quite a per cent. of sand, also streaks of a semi-fire-clay. The clay, when dry, becomes very hard; it does not have so much of the oily or soapy appearance. It requires very heavy machinery to handle it properly, and is one of the hardest clays to burn I have seen. It stands well under the fire and makes a very superior paving-brick.

The clay at Des Moines, Iowa, is very similar to the Sioux City clay in this: that it possesses quite a per cent. of sand and fire-clay. We do not wish to convey the idea that the sand and fire-clay are mixed or in the same vein, for they are not, either at Des Moines or Sioux City; but at both places the clay bank is very high, having a working face of from fifty to one hundred feet, and in both the sand, clay and semi-fire-clay lie in pockets and different layers.

The Des Moines clay is more plastic in the natural state than any other similar clays; in fact, it is found almost soft in portions of the bank, while in other portions it is quite hard and dense. This clay also requires a very high degree of heat, and stands up well in the kiln, and produces among the best paving-brick in the market.

Before passing, we would say that neither the Des Moines nor the Sioux City clays polish in the green state so readily to a smooth surface, and when burned do not break with quite so smooth or gloosy a fracture as some other clays.

At Middleport, Ohio, Garrett & McManigal are manufacturing excellent paving-brick from a deposit made at some time, no doubt, by the Ohio river. This clay is plastic in the bank, has no resemblance whatever to soapstone or shale, is taken out of a flat field near the surface. It has very little sand. When soaked, becomes sticky and tough to the touch, shrinks considerably in burning, but stands up well under fire. Most brick-men would pronounce this a number one red brick clay; in fact, the company was largely engaged in making dry pressed brick before going into the paving-brick business.

At Westerville, Ohio, Mr. J. W. Emerald is making paving-brick from a clay which in appearance seems to be nothing more or less than a surface clay. We do not mean soil. The clay is very dark, almost black. It is very plastic and can be handled easily with the spade, almost free from sand. This is a remarkable clay, one that few would ever suspect as suitable for paving-brick, but teaches that paving-brick material can be found in the swamps and marshes as well as in the hills and bluffs.

The above descriptions are intended to aid to some extent in the identification of paving-brick clays from their physical appearance.

The Bucyrus Brick & Terra Cotta Co., of Bucyrus, Ohio, use a shale clay in the manufacture of their vitrified street paving-brick, which is of an exceptionally fine quality. The analysis of this shale is as follows:

	Parts in 100,000—Metric System of Weights.
Silica	66.66
Alumina	19.20
Iron Oxide—triple	6.18
Magnesia Carbonate	none.
Organic Matter	none.
Lime Carbonate	0.72
Free Oxide Alumina	7.24
	100.00

The analysis of the shale from which the vitrified brick are made and used in Fort Smith, Ark., as given by the State Geologist of Arkansas, is as follows:

	Per Cent.
Silica	58.43
Alumina	22.50
Oxide of Iron	8.35
Magnesia	1.14
Potash	2.18
Soda	1.03
Sulphur	1.16
Loss on Ignition	6.20
	100.99

The Cambria Iron Company, of Johnstown, Pa., has discovered that the shale which is taken from its ore mines will make a superior quality of vitrified street paving-brick. The shale taken from the ore mines and dumped over the bank was thought to be entirely worthless until this discovery was made. Hundreds of thousands of tons of this shale are lying within several miles of Johnstown.

The Grape Creek Clay Company, Grape Creek, Ill., in the manufacture of its street paving-blocks, uses a shale clay which is found overlaying its coal measures at a depth of 120 feet and 160 feet respectively.

The clay on leaving the mines is more like rock than clay.

Shale alone makes a good paving-brick and will never wear out by attrition. Fire-clay alone, as usually worked, possesses a grainy nature; when put in the pavement, will not sustain the amount of traffic without wear that is desirable.

The London Clay Company, of London Mills, Ill., make paving-brick of shale and potter's clay in such proportions as to get good results. The potter's clay, withstanding a high temperature, allows great latitude in the burning without making the brick unshapely by melting or twisting; while the shale, being less refractory, melts and forms a union of all the mass, yet being relieved of their glossy nature, making them tough, and capable of resisting the action of frost, and maintaining a smooth surface in the pavement.

FIRE-CLAYS.

Clays are termed *fire-clays* or *refractory clays*, when they resist exposure to a high temperature without melting or becoming in a sensible degree soft and pasty. These clays differ much in degree of refractory quality. They occur in various geological formations, old as well as recent; but some of the best abound in the coal-measures.

All clays as they occur in nature consist essentially of *hydrous* silicate of alumina, and upon the presence of the water of *combination* depends their fictile or plastic property; that is,

their capability of being moulded into vessels or other objects when mixed with water and kneaded to a pasty consistency. All clays contain *hygroscopic* water, which may be expelled at 100° C. without lessening their plasticity. When, however, clay is heated to redness, it loses not only its hygroscopic water, but also its water of combination, and as a consequence, it ceases to be plastic. In this dehydrated state it cannot directly *combine* with water and regain its plasticity, though it may *absorb* water with avidity. Pounded brick, for example, which is dehydrated clay, may absorb a considerable quantity of water, yet without regaining the slightest degree of plasticity.

It is important to note that there may be great variation in the composition and quality of clay from contiguous beds in the same pit, and even from the *same* continuous horizontal bed in the same locality.

If we compare different clays together in respect to elementary composition, we find the relation between the silica and alumina to be extremely variable; and accordingly, the formulæ which have been proposed to express their rational constitution are very discordant. This is in great measure to be explained by the fact that in many clays a large proportion of silica exists uncombined either in the form of sand, or in much finer state of division. The grittiness of clay is due to the presence of sand.

Geologically speaking, fire-clays are of three distinct formations, viz., cretaceous, the carboniferous or coal measures, tertiary; and they are all used in the manufacture of fire-brick. The first and the last of these are both of them soft and plastic. The coal measures produce both plastic and non-plastic, but the plastic is neither soft nor friable, like the other formations. On the contrary, it is quite hard when freshly mined, though it always lacks the clean-cut fracture characteristic of the non-plastic.

Fire-clays are of many colors, black, dark and light gray, blue, light green, white, both clear and deepening into a bluish

or grayish tint. The flint or non-plastic clays are sometimes clear, of various shades, other times spotted, again of a dark, almost of a chocolate color, with veins running through it, and very beautiful. The different kinds of fire-clay vary so much in hardness that while one is dug with a spade, another has to be blasted in the same manner as rock is quarried.

There are two distinct varieties, non-plastic or flint clay and plastic clay. The former is the most refractory. They are often found in the same vein and interchangeably as regards position. It is difficult to understand how it happens that some clays exist in this flint-like condition, and that they should be so much more refractory than the other, found in the same vein, and perhaps of identical composition. The fact is, however, that the more plastic any clay becomes, either naturally or artificially, the less refractory it is.

In the United States, superior qualities of fire-clays are found in various localities.

In the majority of instances fire-brick plants are located upon the land from which the clays are taken. There are, however, some notable exceptions to this rule. The works of the celebrated fire-brick manufacturers, The Harbison & Walker Co., are located in the city of Pittsburg, Pa., while the fire-clays which they employ are drawn from various parts of the state of Pennsylvania. The fire-clays found at Mount Savage, Md., the "Amboy"clay of New Jersey, and the fire-clays of Farrandsville, Pa., are all highly esteemed, and are among the best fire-clays found in America. The "Amboy" fire-brick are produced from a cretaceous clay, which is first burned in a kiln, its plasticity being lost in the process, and resulting in what is known as "cement." The second, or Mt. Savage brick, are produced from two qualities or varieties of carboniferous fire-clay, one of which has in its natural state the properties of the "cement" just mentioned.

At Mineral Point, Tuscarawas County, Ohio, and at New Lisbon, Ohio, a clay nearly similar to the Mt. Savage clay is found; its appearances and properties are about the same; it is non-plastic, and is treated in the same manner.

For all these clays the "cement" is coarsely ground, mixed with from one-sixth to one-tenth plastic clay, gradually dried and tempered, and then hard-burned.

The fire-brick made from the clay from the coal-measures of Kentucky, Pennsylvania, Ohio, Illinois and Missouri are also held in high esteem.

The following is an analysis of Farrandsville, Pa., fire-clay, by J. Blodget Britton, Iron-Master's Laboratory, Philadelphia, December, 1878:—

Silica	45.26
Alumina	37.85
Sesquioxide of iron	2.03
Lime	.08
Magnesia	.02
Potash	1.26
Water and organic matter	13.30
Oxide of manganese and loss	.20
	100.00

Mount Savage Clay. In the year 1841 the Mount Savage Fire-Brick and Iron Company of Mount Savage, Md., was organized, which name was changed in 1870 to the Union Mining Company of Allegany County, Md.

Mount Savage, Md., is located at the foot of Savage mountain, nine miles north of Cumberland, Md., on the line of the Cumberland and Pennsylvania railroad. The Mount Savage fire-brick have achieved a national reputation for their excellent qualities for use in blast furnaces, rolling-mills, steel plants and gas furnaces. Analysis of Mass. Inst. of Technology:

Silica	50.457
Alumina	35.904
Protoxide Iron	1.504
Lime	.133
Magnesia	.018
Potash	trace
Water and Organic Matter	12.774

Another analysis:

Silica	48.95
Alumina	35.33
Protoxide Iron	1.44
Lime	.34
Magnesia	.07
Potash	trace
Water	13.90

A great many analyses of this clay have been made at various times and by different chemists, but it would not be safe to take any one of the results as a test, for the difference in them is probably due as much to the chemists as to the samples. The following is an average of several results, which will probably give as accurate an analysis as one could obtain:

Silica	55.75
Alumina	33.23
Impurities	2.06
Water	10.37

The bed of clay lies at the very bottom of the coal-measures of this basin. On top of the clay lies an 8-inch bed of coal; beneath it lies from 3 to 4 inches of shale; and then comes the conglomerate rock which marks the baundary of this basin. The bed of clay varies from 8 to 20 feet in thickness.

The clay is divided into two varieties, the hard and the soft; and these are distinguished by their physicial properties. One of these varieties is of a medium gray color, shading almost to black. This clay is very hard, and rattles like crockery when thrown into the chutes. It has a distinct, though not regular, conchoidal fracture; it is non-plastic unless ground to an impalpable powder, and does not crumble much when exposed to the weather in heaps, being affected for only about 3 or 4 inches from the surface, though exposed for years. In parts of the mine this clay, when finally broken, is sharp enough to cut one's hands.

The other variety is a very plastic clay, of much lighter color, weathering very rapidly, and in one season's exposure crumbling to powder.

The peculiarity of this deposit is, that the two clays are so intermixed in the same bed, and in such a way, that in the present development of the mine there is no accounting for the difference in structure of the clay. In one place the bed will be full from roof to floor of hard clay, and in another place, within a few feet of the former, the clay will all be soft. These sudden changes cannot be accounted for. Usually, the soft clay lies on top of the hard, and acts as a sort of protector for it, keeping off the coal water. In some places, again, there is a gradual change from one to the other, from hard to soft and back again; and often the hard clay lies between layers of the soft. This is what causes the difficulty in the mining work and makes it seem irregular; for where the hard clay is struck small pillars and large chambers are made, and *vice versa*.

The impurities in this clay are much the same as in all other clays, except that they are fewer and smaller in amount. There are some balls of iron ore found in the bottom of the bed, but these can readily be seen. The most objectionable impurity is iron pyrites, which is found in the slips of the soft clay, and particularly in the casts of roots in that variety. The detection of these iron pyrites is impracticable until after the brick have been subjected to the intense heat of the kiln, when discoloration is shown in spots on their surfaces.

As will be seen on reference to the analyses, one great reason for the superior quality of the Mount Savage clay is its unusual freedom from potash, one of the worst constituents of fire-clay; the valuable properties of fire-clay being reduced in ratio to the larger percentage of potash which the clay may contain.

Robert Anderson Cook, A. M., who was employed by the Union Mining Company, of Mount Savage, Md., in making such tests as seemed to be desirable to keep the brick up to the best form for any change which might take place in the market, says: "It was not intended that other clays should be brought to mix with those found here; and from tests made here of brick from other places, and calculations from analyses

of other clays, it is doubtful if any could be procured which would be of any advantage in the general run of brick work.

"For the calculations in getting at the value of a fire-clay from its analysis, the formula used was one given by a German chemist, Dr. Carl Bischoff, who is a recognized authority on the subject of refractory materials, and whose investigations on the subject have been carried out and verified to some extent in this country. He divides the clay into two parts, the silica and alumina constituting the refractory part, and the impurities the fluxing part. Dr. Bischoff, in this formula, uses the impurities as a whole, but in another he divides them according to their relative strength as fluxing agents.

"Taking the alumina divided by the total impurities as a dividend, and the result of the silica divided by the alumina as a divisor, the quotient will be a measure of the refractoriness of the clay as compared with that of another clay treated in the same way. Calling RO the impurities, the formula will be as follows:

$$\frac{Al_2O_3}{RO} \div \frac{SiO_2}{Al_2O_3}.$$

"As small a difference as 0.05 between the quotients thus obtained for two different clays indicates a difference in refractory quality which, other things being equal, will show itself in a furnace test.

"These calculations are of great use in the comparison of different clays, but the result one might expect from them may be entirely changed when the clays are made into brick. The physical qualities of all clays must be tested before an absolutely perfect comparison can be made. A sample of the same clay being used by two different brick-makers, yet the one brick made from it may not be as refractory as the other, though the sample may have been thoroughly mixed; for if in one case the clay be coarsely, and in the other finely ground, the coarse one will stand a great deal more heat than the other before it vitrifies to a homogeneous mass.

"This has been observed before; and the writer has found it perfectly true as regards this clay, that the more finely it is ground, the less *refractory* it becomes. At the same time, the more finely it is ground, the stronger and harder the brick becomes, the more abrasion it will stand, and the less likelihood there is of its being broken in handling. Though refractoriness is an essential of fire-brick, yet it is not the only one.

"For the various positions in which the brick are placed, and the duties they are expected to perform, from the upper part of a blast furnace, where the heat is low, and the abrasion of stock is the greatest element in the destruction of brick, to the ports of an open-hearth steel furnace, where intense heat is the most destructive element, particular mixtures of clays should be made to get the best results from raw materials.

"The greatest trouble of a brick manufacturer is that he cannot be sure for what purpose the brick will be used, or in what position in the furnace they will be placed. Another trouble is to find out where the fault lies, when complaint is made. This is almost impossible. It may be in the construction of the furnace, or in bad bricklaying, or the grade of the brick, or that the brick were not hard burned. And if a sample lot of brick is sent to a mill to be tested, the chances are that when the superintendent is asked how the brick stood the test he will have forgotten all about them. The only way for a manufacturer to test the brick is to build a furnace and test them himself, and to do this under, as nearly as possible, the same conditions as those under which they will be used in practice.

"The furnace used by the writer for making such tests had nearly the form of a puddling-furnace. One-half of it was built of one mixture and the other half of another, running through the furnace from end to end. Bridge-wall, roof, side-wall and neck would show how the brick stood in each position. From the results of the tests a fair comparison could be obtained of the value of the brick. The draft was a direct one to the foot of a large chimney, and the coal used was a mixture of the best Cumberland coal and our own. A brick of the

mixtures used in building the furnace was taken as a standard. One of these brick, with another, either of some other mixture, or some brick which we wished to test, were placed side by side in the neck of the furnace, which was then fired as hard as possible for a certain length of time. When the furnace had cooled off the brick were removed, and the effect carefully noted, particularly as regards shrinkage and vitrification, and the effect of the heat on the furnace was also noticed. The heat in 36 hours was intense enough to vitrify any brick, but not enough to destroy them.

"As the demand now is for a hard-burned brick, the difficulty of spotted brick arises. These are brick which appear to be of poor quality, for though a clay may not contain more than 1 per cent. of oxide of iron, yet if it is exposed to great heat these spots will show; and at present, buyers, with the exception of a few who have learned their value, will not take spotted brick. All the brick from the other places, which the writer has tested, will, when exposed to our greatest heat, show some spots, although as they come out of an ordinary kiln they are free from spots.

"The two peculiarities which have made the Mount Savage fire-clay so famous are its freedom from impurities and the fact that this clay contains such a proportion of silica to the alumina that the brick, after they have been hard burned, will swell a little instead of shrinking, no matter how much they are heated."

IMPORTANT PROPERTIES OF FIRE-CLAYS.

The compositions of fire-clays differ very materially, as is shown by the results of the various analyses which have been previously given.

The refractory power of all fire-clay wares is greatly enhanced at very high temperatures by the presence of a large per cent. of alumina.

Chemists tell us that fire-clays will melt the more readily in very high heats in proportion to the per cent. of combined silica which they contain; but that clean, free silica, *i. e.*, in crystals,

mechanically combined, will not melt in our melting heats, unless fluxed. Consequently, they say, a high proportion of free silica, in the absence of a high per cent. of the fluxes, lime, magnesia, alkali and iron, is not nearly so injurious as when the silica is chemically combined.

Every fire-brick manufacturer, who has ever given the subject of combined and free silica attention, and who has made furnace tests of brick containing an excess of free silica, in competition with brick carrying an excess of combined silica, by placing such brick side by side in a furnace, knows that fire-brick are more refractory in proportion as the free silica is replaced by combined silica.

Free silica alone is, of course, infusible, but when it enters into combination with the other bodies commonly present in fire-clays, such clays become the more easily fused the larger the proportion of free silica present.

This raises a very important question, viz.: Whether it is not really essential that there should be made two analyses of the silica contained in any fire-clay; one analysis to determine the per cent. of free silica, and the other to determine the per cent. of combined silica which the clay carries.

The hydrated silicates of alumina used in fire-brick manufacture contain as a rule from 50 to 65 per cent. of silica, 30 to 75 per cent. of alumina, and 11 to 15 per cent. of water. The relation between the silica and the alumina is exceedingly variable, owing to the fact that a part of the silica, which is not always the same, is combined, and a part uncombined; hence the necessity of the dual analysis of the silica just mentioned. The quantity of water is also variable, as part of it is hygroscopic and can be driven off without injury to the clay. The plasticity generally depends on the water of combination, which, when driven off at a red heat, cannot be made to combine again, so that this property is then entirely lost. It contains, beside, a small quantity of other elements, such as potash, soda, lime, magnesia and iron, and is generally less refractory the more it contains of them. When it contains from 6 to 10 per

cent. it will generally melt. When the clay is silicious, 3 to 4 per cent. of other substances make it fusible. When it is aluminous, 6 to 7 per cent. of oxide of iron does not make it lose its refractory qualities, owing to the very refractory nature of most aluminates. When, therefore, the corrosive effects of basic slags are to be feared, aluminous clays must be used.

Almost all clays contain organic matter. The presence of organic matter in fire-clays is, however, unimportant, as it is consumed or removed when the brick are passed through the kiln, as would be the case with an admixture of coal free from ash.

Pure material, composed exclusively of silica and alumina, would be completely infusible. Such material is, however, exceedingly rare. The property of infusibility is always more or less compromised by the presence of foreign substances, which tend to reduce it or take it away altogether. The clay which, according to Brogniard, is the most refractory when deprived of its hygrometric water, has the following composition: Silica, 57.42; alumina, 42.58.

While the refractory nature of the clay is due, to a very great extent, to its chemical composition, it is not due to it alone. There are, probably, no two beds of clay in the world, or even different parts of the same bed, that have exactly the same composition, and yet they may be very nearly of the same quality. The power to resist heat is, undoubtedly, owing to the molecular condition of the particles, a subject which has been but little studied and is but little understood. Many clays, which would be rejected from chemical analysis alone, are sometimes found in practice to be excellent refractory materials. It has been found that the refractory nature of the clay depends also to a great extent on the mechanical arrangement of the particles, for of two materials having exactly the same chemical composition, one being coarse and the other fine, the coarse may be practically infusible, while the fine may be more or less easily fusible. The more porous the same substance is, the more infusible it will be. It may be said in gen-

eral terms that the value of a given refractory clay will be inversely as its coarseness, and as the amount of iron contained. When the amount of iron reaches 5 per cent., the material, as a rule, becomes worthless. This is true, however, only in general, for Petitgand cites an excellent clay from Spain in which there is 25 per cent. of iron. This is, however, an exception.

On this point a recent writer says: "I have before me the results of two analyses of clays just brought up from the laboratory. These clays are very different in composition, and samples are sent five times each month for both analysis and physical demonstration. The mines are both old ones, and each concern, representing two of the largest rival concerns in the United States, has been in business a great many years, but notice the contrast:

	No. 1.	No. 2.
Silica	49.44	50.50
Alumina	34.26	24.00
Iron oxide	7.74	none
Carbonate of lime	1.48	2.70
Carbonate magnesia	1.10	none
Chloride of the alkalies	none	1.80
Organic matter	none	1.01
Moisture, etc.	5.98	19.99
Total	100.00	100.00

"These two clays are in great demand, and are very popular, for precisely the same purposes, with those who use them."

In connection with these analyses attention is invited to the proportion of alumina and iron contained in the two clays. It is safe to say that the greater the proportion of alumina which a clay contains, the less such a clay is affected by the presence of a large per cent. of iron, and this applies to almost as great an extent with reference to alkalies.

In order to be useful, clay should be naturally plastic or should artificially be made more or less plastic, as this property is necessary to their being moulded into the shapes required. This plasticity is owing, first, to the fineness of the particles, to the presence of alumina, and to the water of com-

bination. It is diminished by the presence of iron, lime and magnesia. The refractory nature of the clays, then, is due to the presence of alumina or silica in excess, and to the absence of the fluxes, potash, soda, lime, magnesia and iron.

The characteristics of all fire-clays may be said to be that they do not effervesce with acids, that they make a paste with water, which is absorbed so rapidly as to make a slight noise. This paste can be drawn out without breaking, and is very plastic. When dry, fire-clays are solid, and break into scales when struck. They have a soapy feeling, can be scratched or polished by the nail, can be cut into long ribbons with a knife, and appear somewhat like horn. When fresh from the quarry, fire-clays have a more or less fetid odor, owing to the presence of some partially decomposed organic substanees. In composition they contain, as we have seen, either silica or alumina in excess. Silica in excess makes them rough, and takes away most of their plasticity and tenacity. Alumina makes them very plastic; magnesia makes them very unctuous, and almost soapy, but does not make them fusible; lime makes them dry and fusible. Iron and other substances change their color, and beyond certain very restricted limits make them fusible. The colors, ranging from gray and brown to black, are owing to a small percentage of bituminous material. White clays are generally considered the best, but there is no certainty about it, as they often crack, or even melt. It is generally an excellent sign when they leave unbroken lines when scratched by the nail. It is, however, never safe to judge by the eye or touch, as some of their chief characteristics apply equally well to materials not in the least refractory, and even those that are peculiar to them may be taken away by improperly drying them, by carelessness in storing or handling them, or by allowing them to become mixed with other substances. A preliminary analysis gives only a general idea of their nature, but it is not always a safe guide to the manufacturer, who needs first an analysis and then an assay, for some of the most inferior clays, if we should judge by their analyses, give excellent results when used as

mixtures. Analysis is necessary both before and after the assay, but there is a molecular force which seems to exert a greater influence in imparting a refractory value to the material than is exerted by the chemical composition. The greater this force, the less likely is the heat to overcome it, either to cause disintegration or chemical union. If possible to do so, all clays should undergo some process of preparation, with a view of purifying them.

Every person using clays should endeavor to get a certain knowledge of their properties by assay. There have been a number of these assays published, most of which, though they give accurate results, are too complicated for ordinary use. The two simplest and best are those prepared by Bischoff and the foil assay.

Bischoff's assay is based on the comparison of every clay with one from Garnkirk, in Scotland, which is taken as a type. For this purpose, the clay to be examined is mixed with one, two, three to ten parts of quartz, as the case may be. It is then raised to a known temperature and compared with a piece of the type clay of the same size and shape, which has been submitted to the same temperature. If the clay with three parts silica acts like the Scotch clay with one it is called three, and so on. The best and simplest assay seems to be the one made by the blow-pipe, which consists in mixing a small quantity of clay with water, and then spreading it out carefully on a piece of platinum-foil in a very thin sheet, which, when completely dried, is submitted to the flame and compared with clay of known fusibility and prepared in the same way.

For many purposes the density of a clay is an important element of consideration. When strong fire-brick are needed, or glass-house pots, a dense, solid clay is desirable. One of the superior qualities of the celebrated Stourbridge clay of England, and that from Coblentz, Germany, as also the Missouri clays, is their comparatively great density. That of the first named is 2.435 to 2.553; that of the Coblentz, 2.229 to 2.266; that of the Cheltenham clay, Missouri, 1.708 to 1.715; that of the Evans mine, Missouri, 1.759 to 1.789.

The specific gravity of the clays examined by the State Geologist of New Jersey was determined as follows:—

A prism about an inch in length was cut off the solid mass. This was covered by a film of paraffine and weighed, first in air, then in water.

A few were taken in this way; afterward the prisms were placed in water, in a glass vial very little larger than the clay, and then weighed. No water was absorbed by the clay in this modification of the method.

By this method the openness or porous condition, which affects the density, was taken into account. The ordinary method neglects this condition, and the specific gravity as obtained is that of the clay, sand, etc., or solid mass, without any reference to the spaces or interstices between the particles of solid matter.

BOND CLAY.

The problem of making a refractory brick from native clays is based upon the fact that "the purer the clay the more infusible." Our purest clays are flint-clays, which are probably refractory by reason of their structure as well as their composition. These then make an admirable basis for the brick. As they are non-plastic, their successful use compels the addition of a small amount of plastic clay, and on the choice of this clay all depends. A fine-grained, sandy clay, hard in its native state, and plastic when ground up in water, makes the best bond; it is needless to add it should be pure. The more aluminous a clay is, the more will it shrink on burning, and if the clay which has been used to incorporate the non-plastic part should shrink materially on burning, it would loosen the bond between the pieces of hard clay and make the whole fabric unsound. Therefore, the clay fit for a bond is one in which the natural shrinkage is at a minimum; this condition is found in a fine-grained, sandy clay. It is ignorance of this point, which seems so simple, that has caused the failure of so many patent mixtures for refractory materials. It has seemed

to each man in succession who has approached the subject, that as pure kaolin is infusible, and pure sand is infusible, and as these bodies represent respectively our ideal of plasticity and non-shrinking qualities, a proper mixture of the two should produce the most desirable results. But, when such a mixture is heated, the enormous shrinkage of the kaolin loosens the bond of the whole body and makes it weak and fragile.

If, then, a pure, sandy and plastic clay can be found, the bond is one likely to be satisfactory; but the main trouble is in a lack of purity, for if a clay fills the other conditions required, it is liable to be impure like a stoneware clay.

Sufficient attention has not been given by fire-brick manufacturers generally to the structure of the fire-brick as it relates to the size and distribution of particles of flint-clay, which forms the base of first-class brick, and to the bond clay that cements the particles together. Before it can be determined what is required, it must first be ascertained how or why a brick fails or wears away in the furnace. A practical manager in one of the largest steel works using the Siemens furnaces, and who has given close attention and much study to this subject, says, that where the particles or small pebbles of flint-clay in the brick are of good quality they do not fuse or melt, and that it is the bond that holds the thicker particles that runs—the coarse particles floating away on the fluid bond-clay. He also says that large particles should not, for this reason, be in the brick, and the flint-clay should be prepared or screened so as to represent in size ordinary bird-shot, nothing larger, and it should be as free from dust as possible, using as little bond-clay as is necesrary to make a sound brick. When the clay is so prepared another fault arises, which is this: The object of the wet-pan is not to grind what is already sufficiently fine, but only to mix and toughen the clayey mass so that when the clay is sufficiently mixed it should be immediately taken out of the pan; otherwise, by longer grinding, these particles are rendered too fine, as the extra grinding, in place of improving the quality of the mixture, depreciates it. To achieve this

equality in the size of the grains of the clay an improvement might be made in the way the material is screened. Perforated sheet-iron screens are almost in general use, over which the clay as it comes from the dry-pan slides over the dust, and a portion of the small pebbles go through the screens. On putting your hand into the chute which conveys the screenings back to the dry-pan, you will find that if passed through a hand-screen one-half of the material ought to have been passed to the bin, being already sufficiently fine. To obviate this objection there should be used a circular revolving screen, twelve wires to the inch, fixed slightly lower at one end than the other, so that, as the clay is delivered into the higher end, the revolving screen will throw it from side to side, entirely removing every particle of the required size, the rough screenings falling out at the lower end.

DIGGING, MINING AND MARKETING FIRE-CLAYS.

The extraction of the clays, feldspar, kaolins, fire-sand and other materials occurring in the plastic clay belt of the State of New Jersey, is mostly accomplished by digging pits in the beds worked, the overlying strata having been previously removed. The removal of the superficial beds, or "bearing," as it is frequently termed, and the digging, vary somewhat in the details according to the nature of the circumstances of location, relation to water, cost of labor, prices of materials, transportation, and business management.

The first work on opening a clay bank, after satisfactory exploration, is to remove the top dirt or bearing. This is done in wagons in case it has to be carried to some distance, or else by cars on a movable track. Wheelbarrows are occasionally used. At older banks, where a large amount of clay is dug, a car-track, or tramway, generally runs from the bank to the point of delivery—main lines of railroads, or to docks on navigable water—and in these the track is generally laid quite to the heading or face of the bank, or alongside of it, so that the cars can be easily loaded. This material is taken outside to the

nd. Teams are in use as the motive power, be-
an steam, and quite as effective in short distances.
aterials of this bearing are of probable value, they
put by themselves preparatory to future use, or
ipped, as desired. Whenever, in working banks,
ations, areas have to be filled, the top dirt is used
se.

to the general practice, the digging advances by
f contiguous pits, and the dirt of the pit which is
ed is thrown at once into that which has just been
e cases it is sufficient to use the dirt from the
v pit, and the necessity of removal to dump or
s avoided. But this is exceptional, as in most
amount of top dirt is in excess of that needed for
e surplus must be removed.

removing the top dirt depends on so many and
y varying conditions that it is not possible to give
nature of the strata, the distance of removal, the
and other items, enter into the cost.

op dirt nearly everywhere is earthy, the employ-
n excavators or similar machinery is certainly
The introduction of larger capital and more com-

an oblong pit of about the same area. These are dug through the beds of value, or as deep as practicable. Generally they are made of sufficient depth to extract all of a given bed of clay, feldspar, kaolin, or other material, which may be worked, and the digging or pitting stops at the bottom of that bed. Thus in the fire-clay banks, they are dug through that stratum, although in some places where there are valuable beds underneath this, the digging is continued into these lower beds. The work is often stopped on account of the water in some pits; the danger of caving in, water flooding and other such circumstances, determine the depths of the workings.

It is customary to have on the ground at the side of the pit a platform of a few boards, on which the clay or other material is thrown, and if needed, the clay is sorted into different grades. This sorting is done piece by piece as the spits are dug. A gouge spade is used in digging the clay. This differs from the common spade in having its blade cylindrical, and the upper edge is broader than that of the common spade, a tread to receive the weight of the pitman, neceesary to cut down into the solid clay bed. The lump of clay, or spit, as it is called, thus loosened is taken by another workman, who cuts out any nodules of pyrites that may be in it, or any other foreign matter which can be removed by a knife, and thrown on the platform. This workman sorts the clays for ware, fire-brick, paper, alum, pipe, or other grades. The pitman confines his operations to cutting down the clay, continuing this over the pit area, and then begins a new spit level, and so proceeds till the bottom of the bed is reached.

In some of the clay banks the working floor or base is lower than the top of the clay bed, or on a level with the bottom of the bank. The digging of these banks is not properly by pits, although it goes forward by a succession of pit-like excavations. The platform for the clay is below; the carts are driven to the side of the bank and loaded at once by the workmen; or the clay is carted to heaps near by and there stored, each grade or variety by itself, or it is taken to boats or cars for transportation to market.

Wherever the sides or the walls of the pits or banks are liable to fall in, these have to be strengthened and the workmen protected by planking and bracing. In pits of ordinary size, three heavy planks on a side are sufficient, with bracing timbers placed across between the opposite sides. Excavation into the bank and above a working level is not often attended by such dangers. The lateral thrust in pits appears to be the more common cause of slides or caving. In sinking pits it is necessary and customary to leave walls of clay 1 to 2 feet thick on the sides which have been worked. These act to hold up the ground and keep out the water. Most of the danger from slides comes from these walls, and the pressure of wet drip behind them. After the pit is dug and before it is filled up, a part of the clay walls is taken out so that as little as possible is left in the ground.

Occasionally picks are used instead of the gouging spade, when the clay is very hard and compact. At a very few localities blasting by powder is employed to break up extra hard clay or strong layers associated with it. Undermining and splitting off large masses of earth, clay, etc., by wedges or powder are practiced at banks where the materials are of a coarser or less valuable character. This is common at the red brick clay banks. It consists in digging under at the foot of the bank as far as can be done with safety, and then either allowing the undermined mass to tumble of itself, or to force it off by using powder or wedges at the top of the bank. In this manner hundreds and thousands of tons are tumbled down at once and broken, making the handling much easier than the removal of an equal weight by spading and shoveling down from the bank.

As the beds of clay are nearly always impervious to the flow of water, there is no water to be removed, except the very little rain-water which falls or the leakage from the surface drain about the top of the pits. This is usually allowed to accumulate in a deeper corner of the pit, and is bailed out from time to time with a bucket. As the time for sinking a pit of the

ordinary size does not often exceed two or three days, there is little water from these sources. The greatest amount of water comes from the sand or other layers which are sometimes interstratified with the clay, and which allow the water to percolate quite freely through them. Sometimes the clay bed is found to be quite sandy in the middle and to allow water to leak through.

At most of the clay banks the bed of clay is underlaid by sand, kaolin, or sandy clay, and these strata are generally full of water, so that the bottom of the pits is wet, and the pits soon fill with water if it is not pumped out or they are not filled at once with earth. In banks where all the clay bed is above the working floor, open ditches or partially covered drains are constructed so that the water can run off without further inconvenience or cost.

In pits the water has to be hoisted to the level of the working floor, and thence carried off by drains. Various modes of raising water are in use; the most common is by a pump worked by hand at intervals, as it is necessary to keep the pit clear and in working condition.

Hoisting by buckets and a windlass has been used in a few localities. Steam power has also been employed in some places, where the depth of the pits and the surrounding wet ground, as in tide-meadows, furnished a large quantity of water to be raised. The judicious arrangement of the location and appliances so as to avoid heavy expenses in keeping water from the pits, has much to do with the profits of clay digging. Comprehensive plans and skillful management are as important in this as in any other department of industry. The profits of clay digging have in some instances been very large, but for lack of judicious plans they have not been long continued.

At a few places in New Jersey the extraction of the clay has been by underground work or mining. This consists, on side-hills, in cutting short drifts, or tunnels, in the clay bed, timbering them so as to hold up, temporarily, the superincumbent earth, and when the work is done, allowing it to fall in. By a

series of drifts side by side most of the bed is in this way worked out.

There is some loss of material in the clay which has to be left at the bottom as a floor, and at the top as a roof to hold up the overlying sand or other loose material, and to keep out the water. These drifts are inclined a little, if the bed allows any inclination, to let any water which may get in them by accident run out. They are narrow, being only wide enough for the passage of men with their barrows or carts. The timbering consists of upright posts set at the sides, at varying distances apart, sometimes close together, and at others a foot and a half or two feet apart. Upon these, cross-beams or sleepers are laid to support the roof. These drifts are seldom more than 100 feet long. Wherever the beds of clay are uniformly thick, the bearing heavy, and the clays of superior quality and value, it may be practicable and more economical than the ordinary mode of stripping off the top and pitting the clay. It is costly and attended with risks; and these objections must be considered in its application to any locality. It is believed that the scarcity of clay at easily accessible depths for open working will in the future compel the attention of clay-miners to it as practicable, and the only way in which some of the New Jersey clay territory can ever be made available and productive.

The digging of fire-sand, kaolin, and feldspar is carried on very much like that of the clays. As the strata are not impervious to water the pits are generally smaller, so that the length of time in sinking one is seldom more than a day. The quantity of water to be raised is commonly much greater, and in some cases it is so large that it is scarcely possible or practicable to get to the bottom. In working the strata of these materials there is more loss than in digging clay. More of the bed is left in the ground. In digging these the gouge spade is rarely used, but ordinary shovels and spades, aided occasionally by picks where the material may be more firm or too hard for spading. The loading is generally direct from the pit or the side platform into carts or cars, and there are fewer grades, rarely more than number one and number two.

Nearly all of the clays, and all of the feldspar, kaolin, and fire-sand, are sent into market in a crude state. They are shipped in bulk, either in boats or cars. With some varieties, as the paper and ware clays, more care is taken in keeping them clean and free from admixture with inferior grades. Formerly the paper-clays were shipped in barrels, but at the present time they are generally transported in bulk.

The mines from which fire-clays are taken should be kept in first-class condition, so as to be able to meet all demands made upon them for raw material, and nothing but pure clean materials should be sent to the factory to be made into fire-brick.

In mining fire-clay more care is required than in mining iron ores, or even coal. It is considered good ore that produces fifty per cent. metallic iron; the other half consists of foreign ingredients that are run off from the furnace as slag. An accidental or careless increase of this foreign matter results in no more serious consequences than the lessening of the percentage of metallic iron produced, thus causing a slight increase in the cost of the pig-iron. The case is very different with fire-clay. Foreign matter carelessly mixed in with fire-clay may easily spoil a large quantity of brick. Fire-clay often runs in veins contiguous to iron ore or limestone, or even closely associated with them, and it takes but little of either of them to ruin a large quantity of clay. The writer remembers a case in point where a part of the clay supply came from a mine where the clay bed was directly under the limestone. The latter was first got out, going to the furnace for flux; afterward the fire-clay was taken out. Some slight changes among the hands employed at the mines resulted in a quantity of the small limestone chippings getting mixed with the fire-clay. As they were both the same color, it passed unnoticed until some thousands of brick were spoiled.

In many fire-clay mines streaks or spots come in at irregular intervals, confined to no particular line in the vein, of foreign matter very injurious to the clay, or sometimes clay strongly impregnated with calcareous or ferruginous matter, that need

great care in order to separate them; hence none but experienced men should be employed for the work, men who by long practice can tell good clay from bad as if by second nature.

The Glenboig Union Fire Clay Company, Limited, of Glasgow, Scotland, mines its fire-clay near Glenboig. On making the descent of the shaft, the total depth of which is about seventeen fathoms, while in transverse section it measures 13 by 4½ feet, we find the clay at the working face to be of a very hard texture, and requiring to be blasted. The method of working is that which is called in Scotland the "stoop-and-room" system—*Anglicé*, "pillar-and-stall." Some of the pillars or stoops are 30 feet square; others are 60 feet, and those immediately around the bottom of the shaft are about 70 feet square. There is an excellent roof to the workings—generally about three feet of rough, hard sandstone. The pumping is effected by means of a double action steam-pump. It has a continuous water discharge, which is delivered by means of a four-inch pipe to a tank situated at the back of the works, and at such an elevation that the water can flow by gravitation to the steam boilers, condenser, etc. The pit is worked by a horizontal fourteen-inch cylinder high-pressure engine, and winding gear embodying all the latest improvements.

The fire-clay, which is got in irregular masses, frequently weighing one or two-hundred weight or more, is raised to a height of about 35 feet above the pit mouth, and run out on a tramway either to a clay "bing" or direct to the crushing mill. When the clay is exposed to the weather for some time, it becomes physically disintegrated to such an extent that the subsequent crushing operation is very easily effected. By weathering, the clay is also rendered much more suitable for the production of such goods as require a fine surface texture.

The following tables of analyses made in the laboratory of the Geological Survey of New Jersey, are here presented as a convenient arrangement of facts for reference. In the first column the silica which is in combination is given; in the second, the alumina; in the third, the water of combination; in

the fourth, the sum of these three constituents, or the essential elements of a clay; in the fifth and sixth, the titanic acid and quartz sand appear; in the seventh, the sum of these two; in the eight, ninth, tenth, eleventh, and twelfth are given the potash, soda, lime, magnesia, and sesquioxide of iron; the thirteenth gives the sum of these; the fourteenth has the hygroscopic water (moisture), fluxing agents. In the last column the total of the constituents determined is placed.

TABLE OF ANALYSES OF FIRE-CLAYS AND ASSOCIATED REFRACTORY MATERIALS.

Made in the Laboratory of the Geological Survey of New Jersey.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Silica (combined) (SiO_2).	Alumina (Al_2O_3).	Water (combined) (H_2O).		Titanic acid (TiO_2).	Silica (quartz sand) (SiO_2).		Potash (K_2O).	Soda (Na_2O).	Lime (CaO).	Magnesia (MgO).	Sesquioxide of iron (Fe_2O_3).*		Water (hygroscopic) (H_2O).	Total.
	RARITAN FIRE-CLAY BED.															
1	William B. Dixon, Woodbridge	31.12	26.95	9.63	67.70	1.90	28.81	30.71	traces	traces	—	0.07	1.24	1.31	0.57	100.20
2	David Flood, Southeast of Bonhamtown	—	—	9.60	—	—	—	—	0.42	—	—	—	—	—	—	—
3	B. Ellison, South-southwest of Bonhamtown	17.90	15.50	4.90	38.30	1.60	57.35	58.95	0.17	—	—	—	1.20	1.37	1.30	99.92
	WOODBRIDGE FIRE-CLAY BED.															
4	William H. Berry, Woodbridge	40.50	35.90	12.80	89.20	1.30	6.40	7.70	0.28	0.16	—	—	1.10	1.54	1.50	99.94
5	Loughridge & Powers, Woodbridge	42.23	39.53	13.59	95.35	1.40 with Al_2O_3	0.50	1.90	0.41	0.08	0.10	—	0.50	1.09	1.21	99.55
6	Loughridge & Powers, Woodbridge. Extra sandy	20.00	18.92†	6.70	45.62		51.80	51.80	0.48	—	—	—	0.88	1.36	0.50	99.28
7	A. Hall & Son, Woodbridge	42.05	35.83	12.20	90.08	1.10	5.70	6.80	0.44	—	—	0.11	0.77	1.32	1.50	99.70
8	H. Cutter & Sons, Woodbridge	43.90	38.24	14.10	96.24	1.30	1.10	2.40	0.15	0.00	traces	0.11	0.96	1.22	0.70	100.56
9	W. H. P. Benton, Woodbridge	42.00	37.56	14.60	94.16	1.40 with Al_2O_3	1.40	2.80	0.35	0.37	—	—	1.04	1.76	0.80	99.52
10	Charles Anness & Son, Woodbridge	34.30	31.66†	10.50	76.46		20.60	20.60	1.53	—	—	—	0.74	2.27	0.60	99.93
11	Crossman Clay and Mfg. Company, Raritan River	37.85	35.75	12.30	85.90	1.60	10.50	12.10	0.37	—	—	traces	0.95	1.32	1.60	100.32

* In some of the clays a part of the iron exists as FeO.

† Alumina and titanic acid.

TABLE OF ANALYSES.—*Continued.*

	1 Silica (combined) (SiO_2).	2 Alumina (Al_2O_3).	3 Water (combined) (H_2O).	4	5 Titanic acid (TiO_2).	6 Silica (quartz sand) (SiO_2).	7	8 Potash (K_2O).	9 Soda (Na_2O).	10 Lime (CaO).	11 Magnesia (MgO).	12 Sesquioxide of iron (Fe_2O_3).*	13	14 Water (hygroscopic) (H_2O).	15 Total.
WOODBRIDGE FIRE-CLAY BEDS.—*Continued.*															
12 Crossman Clay and Mfg. Company, No. 2 fire-clay	—	—	7.00	—	—	40.00?	—	0.21	—	—	—	0.78	—	—	—
13 R. N. & H. Valentine, Sand Hills	39.80	36.34†	12.90	89.04	with Al_2O_3	8.10	8.10	0.15	—	—	0.04	1.01	1.20	1.20	99.54
14 Charles A. Campbell & Co., Sand Hills. White fire-clay	36.20	35.94	12.10	84.24	1.50	12.20	13.70	0.08	—	—	—	0.96	1.04	1.10	100.08
15 Freeman & Vanderhoven, Near Bonhamtown	47.10‡	36.33	13.60§	—	1.60	—	—	0.20	—	—	—	1.07	1.27	—	99.90
SOUTH AMBOY FIRE-CLAY BED.															
16 E. F. Roberts, Pits near Eagleswood	40.40	38.40†	12.50	91.30	with Al_2O_3	5.20	5.20	0.59	—	0.22	0.25	1.20	2.26	1.30	100.06
17 E. F. & J. M. Roberts, Near South Amboy	42.71	39.24	13.32	95.27	1.60	0.70	2.30	0.47	0.42	0.20	—	0.46	1.55	1.58	100.70
18 E. F. & J. M. Roberts, (Selected)	44.20	39.14	14.05	97.39	1.05	0.20	1.25	0.25	—	—	—	0.45	0.70	0.90	100.24
19 George Such, Burt's Creek, washed clay	42.90	38.34	13.50	94.74	1.20	1.50	2.70	0.26	0.18	—	—	0.86	1.30	1.10	99.84
20 Sayre & Fisher, Sayreville	41.10	38.66	13.55	93.31	1.20	3.10	4.30	0.28	0.18	—	—	0.74	1.20	1.00	99.81

* Weighed as Fe_2O_3; part of iron exists as FeO.

† Alumina and titanic acid.

‡ Combined silica and quartz sand together.

§ Water (combined) and moisture.

TABLE OF ANALYSES.—*Continued.*

No.	Locality	1 Silica (combined) (SiO_2).	2 Alumina (Al_2O_3).	3 Water (combined) (H_2O).	4	5 Titanic acid (TiO_2).	6 Silica (quartz sand) (SiO_2).	7	8 Potash (K_2O).	9 Soda (Na_2O).	10 Lime (CaO).	11 Magnesia (MgO).	12 Sesquioxide of iron (Fe_2O_3).*	13	14 Water (hygroscopic) (H_2O).	15 Total.
	FELDSPARS.															
21	W. N. Weidner, Forbes farm, Perth Amboy Twp.	16.85	18.80‡	4.90	40.55	with Al_2O_3	58.40	58.40	0.15	0.21	—	—	0.49	0.85	0.80	100.60
22	Edgar Brothers, Woodbridge Township	16.50	17.46	6.30	40.26	0.90	57.10	58.00	0.12	0.21	—	—	0.54	0.87	0.50	99.63
23	Knickerbocker Life Ins. Co. Farm, Perth Amboy Township	77.40†	16.07‡	4.30§	—	—	—	—	0.15	—	—	0.25	0.53	0.93	—	98.70
	KAOLINS.															
24	Merritt's, Perth Amboy Township	—	17.10‖	4.50§	—	—	77.10†	—	1.30	—	—	—	—	—	—	100.00
25	Charles A. Campbell & Co., Staten Island	—	5.70‖	0.70§	—	—	92.70†	—	0.35	—	—	—	—	—	—	99.45
26	Whitehead Estate, Washington	—	7.80‖	2.60§	—	—	89.40†	—	—	—	—	—	—	—	—	99.80
	FIRE SANDS.															
27	A. Hall & Sons, Fire-sand	—	3.15	—	—	—	96.30†	—	—	—	—	—	0.55	—	—	—
28	A. Hall & Sons, Fire-sand	—	6.65	—	—	—	92.50†	—	—	—	—	—	0.85	—	—	—
29	M. Compton's, Southeast of Bonhamtown	—	1.45‖	—	—	0.25	98.00†	—	0.20	traces	traces	—	—	—	—	99.90
30	M. Compton's, Fine-grained	—	2.10‖	—	—	—	96.40†	—	—	—	—	—	—	—	—	—

* Weighed as Fe_2O_3: part of iron exists as FeO.
† Combined silica and quartz sand together.
‡ Alumina and titanic acid.
§ Water (combined) and moisture.
‖ Alumina and sesquioxide of iron.

TABLE OF ANALYSES.—*Continued.*

	1 Silica (combined) (SiO_2).	2 Alumina (Al_2O_3).	3 Water (combined) (H_2O).	4	5 Titanic acid (TiO_2).	6 Silica (quartz sand) (SiO_2).	7	8 Potash (K_2O).	9 Soda (Na_2O).	10 Lime (CaO).	11 Magnesia (MgO).	12 Sesquioxide of iron (Fe_2O_3).*	13	14 Water (hygroscopic) (H_2O).	15 Total.
CLAYS UNCLASSIFIED.															
31 W. N. Weidner's white clay, Martin's dock	45.10	38.60†	10.90	94.60	with Al_2O_3	0.70	—	2.24	0.25	—	—	1.00	3.49	1.00	99.79
32 Island Farm, ——— ———	45.20	34.85	13.60	93.65	1.40	0.50	1.90	0.12	traces	0.25	traces	1.35	1.72	2.80	100.07
33 Isaac Webster's, Ten-Mile Run, Somerset County	38.20	35.09	11.80	85.09	1.30	8.60	9.90	2.44	0.21	—	0.21	1.89	4.75	0.30	100.04
34 A. J. Dishrow, White clay, Old Bridge	24.55	19.85	5.70	50.10	1.00	44.80	45.80	1.90	0.32	—	—	1.00	3.22	0.90	100.02
35 Mrs. Clark, South Amboy	19.50	17.58†	4.50	(41.58)	with Al_2O_3	53.20	—	2.24	—	traces	0.43	1.42	4.09	1.20	100.07
36 S. A. Meeker, Sandy clay, Woodbridge	19.44	21.83†	5.90	47.17	with Al_2O_3	48.40	—	2.24	—	0.28	0.24	1.57	4.33	0.80	100.70
37 William H. Berry, Sewer pipe-clay, Woodbridge	67.70‡	19.91	5.50§	—	1.00	—	—	2.56	—	—	0.72	1.69	4.97	1.00	100.08
38 H. Cutter & Sons, Black clay, Woodbridge	56.00‡	20.75	10.67	—	0.95	—	—	0.91	—	0.22	0.18	1.60	2.91	2.40	100.41
39 Isaac Inslee, Top (pipe) clay, S. of Woodbridge	54.80‡	28.80	7.80	—	1.00	—	—	2.97	—	0.20	0.64	2.20	6.01	1.50	99.91
40 W. H. P. Benton, Pipe-clay, Woodbridge	33.00	23.80†	6.70	63.50	1.70	29.10	30.80	2.01	0.76	traces	0.57	1.60	4.94	1.00	100.24
41 Crossman Clay and Mfg. Company, Top white clay, Raritan River	64.00‡	29.08	6.80§	—	—	—	—	2.64	—	—	—	1.12	3.76	—	—
42 Sayre & Fisher, Front brick clay, Sayreville	28.30	27.42	6.60	62.32	1.00	27.80	28.80	2.71	—	—	0.18	2.68	5.57	2.90	99.59

* Weighed as Fe_2O_3; part of iron exists as FeO.

† Alumina and titanic acid.

‡ Combined silica and quartz sand together.

§ Water (combined) and moisture.

TABLE OF ANALYSES.—*Continued.*

	1 Silica (combined) (SiO_2).	2 Alumina (Al_2O_3).	3 Water (combined) (H_2O).	4	5 Titanic acid (TiO_2).	6 Silica (quartz sand) (SiO_2).	7	8 Potash (K_2O).	9 Soda (Na_2O).	10 Lime (CaO).	11 Magnesia (MgO).	12 Sesquioxide of iron (Fe_2O_3).*	13	14 Water (hygroscopic) (H_2O).	15 Total.
CLAYS FROM TRENTON AND SOUTHERN NEW JERSEY.															
43 Washed Clay, Trenton	45.30	37.10	13.40†	95.80	1.40‡	—	—	1.30	—	0.17	0.22	1.30	2.07	—	100.19
44 Dr. C. C. Abbott's clay, Trenton	70.05§	19.43‖	7.00†	—	—	—	—	1.60	—	—	—	1.52	3.12	—	[illegible]
45 Joshua Eayre's best white clay, Florence Heights	26.57	21.06‖	5.80	53.43	with Al_2O_3	40.50	40.50	2.47	0.21	—	0.60	1.98	5.26	0.80	99.99
46 J. D. Hylton's fire clay, Pensauken Creek	17.50	18.11‖	5.50	41.11	with Al_2O_3	56.80	56.80	0.76	0.20	0.11	—	1.09	2.16	0.40	100.47
47 B. A. Lodge's clay, Billingsport	16.20	15.00‖	7.70	38.90	with Al_2O_3	56.00	56.00	1.68	0.30	—	0.32	1.20	3.50	1.10	99.50
48 James Conrad's clay, Conrad, Gloucester County	29.50	23.30‖	7.00	59.80	with Al_2O_3	34.50	—	1.77	0.16	—	—	1.50	3.43	1.60	99.33
CLAYS FROM DELAWARE, MARYLAND AND PENNSYLVANIA.															
49 Trucks & Parker, washed clay, Hokessin, Delaware	40.72	34.10	12.35	87.15	0.00	6.50	6.50	1.64	0.27	—	0.39	2.40	4.70	1.35	99.81
50 Woodland fire-clay, Woodland, Clearfield Co., Pa.	42.15	31.43	9.40	82.98	1.60	10.25	11.85	2.01	—	—	0.32	1.57	3.90	1.20	99.93
51 Flint clay, Solomon's Run, near Johnstown, Pa.	42.95	37.02	12.60	92.57	1.70	3.85	5.55	0.20	—	—	—	0.88	1.08	0.80	100.00
52 Mineral Point fire-clay, near Johnstown, Pa.	44.95	38.84	12.50	96.29	1.55	0.30	1.85	0.35	—	—	—	0.91	1.26	0.70	100.10
53 Mount Savage fire-clay, Mount Savage, Maryland	39.90	30.08	7.60	77.58	1.15	16.90	18.05	2.30	—	—	—	1.67	3.97	0.90	100.50

* Includes some FeO.

† Water (combined and hygroscopic).

‡ In an analysis previously printed this appears as zirconia.

§ Combined silica and quartz.

‖ Alumina and titanic acid.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Silica (combined) (SiO_2).	Alumina (Al_2O_3).	Water (combined) (H_2O).		Titanic acid (TiO_2).	Silica (quartz sand) (SiO_2).		Potash (K_2O).	Soda (Na_2O).	Lime (CaO).	Magnesia (MgO).	Sesquioxide of iron (Fe_2O_3).*		Water (hygroscopic) (H_2O).	Total.
CLAYS FROM INDIANA, ILLINOIS AND MISSOURI.															
54 China clay, from Huron, Lawrence Co., Indiana.....	40.10	36.35	22.60†	99.05	0.00	0.40	0.40	0.14	—	—	0.13	0.15	0.42	—	99.87
55 Potters' clay, from Pope Co., Illinois..................	34.70	31.34	12.00	78.04	—‡	12.20	12.20	0.79	0.16	—	0.10	0.16	1.21	8.00	99.45
56 Utica clay, Utica, La Salle Co., Illinois........	38.25	26.45	9.80	74.50	1.15	18.40	19.55	1.10	—	—	0.30	2.10	3.50	2.10	99.65
57 Fire-clay, Winchester, Illinois................	23.15	17.08	6.30	46.53	0.90	46.70	47.60	1.10	—	—	0.28	3.47	4.85	1.20	100.18
58 Fire-clay, Cheltenham, Missouri..............	38.10	31.53	11.30	80.93	1.50	12.70	14.20	0.40	—	—	traces	1.92	2.32	2.50	99.95
59 Fire-clay, Evans' mines, Montgomery Co., Missouri.........	43.93	40.09§	13.80	97.82	with Al_2O_3	0.60	—	0.20	—	—	—	0.88	1.08	0.50	100.00
BRITISH FIRE-CLAYS.															
60 Garnkirk fire-clay, No. 1, Garnkirk, Scotland	44.35	35.30	13.70	93.35	0.95	1.30	2.25	0.75	—	—	—	1.60	2.35	2.70	100.65
61 Glenboig, Star fire-clay	30.40	24.68	9.00	64.08	1.10	31.05	32.15	0.20	—	—	0.10	1.67	1.97	1.90	100.10
62 Glass pot-clay (strong), Stourbridge, Worcester Co., Eng. ..	30.50	22.52	8.30	61.32	1.00	33.65	34.65	0.50	—	—	—	1.43	1.93	2.10	100.00
63 Glass pot-clay, Stourbridge, England	30.29	27.68	9.36	67.33	1.05	26.80	27.85	0.43	—	—	0.36	1.88	2.67	1.44	100.29
64 "Derby clay," John Knowles & Co., Burton-on-Trent, Derbyshire, Eng..	46.10	35.24	10.30	91.64	—‡	1.70	1.70	1.96	—	—	—	2.26	4.22	3.00	100.56
65 Crucible fire-clay, Halifax, Yorkshire, England	39.45	32.19	11.80	83.44	—‡	11.80	11.80	0.51	—	—	—	2.65	3.16	1.60	100.00
66 China clay, Redruth, Cornwall, England	28.40	24.11	7.20	59.71	0.20	37.80	38.00	0.96	—	—	—	0.79	1.75	0.70	100.16
67 Fire-clay, Blaydon Burn Colliery, near Newcastle-on-Tyne	43.00	30.92	9.60	83.52	—‡	10.50	10.50	1.96	—	—	—	1.98	3.94	1.70	99.66

* Includes some FeO.

† Combined and hygroscopic.

‡ Undetermined.

§ Alumina and titanic acid.

TABLE OF ANALYSES.—*Concluded.*

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Silica (combined) (SiO_2).	Alumina (Al_2O_3).	Water (combined) (H_2O).		Titanic acid (TiO_2).	Silica (quartz sand) (SiO_2).		Potash (K_2O).	Soda (Na_2O).	Lime (CaO).	Magnesia (MgO).	Sesquioxide of iron (Fe_2O_3).*		Water, hygroscopic (H_2O).	Total.
	FIRE-CLAYS FROM BELGIUM AND GERMANY.															
68	Fire-clay, Soree, Belgium	41.70	33.50	10.65	85.85	—†	8.20	8.20	1.40	—	—	—	2.05	3.45	2.50	100.00
69	Fire-clay, Frankenthal-on-Rhine, Germany ...	41.90	31.69	9.45	83.04	0.90	8.10	9.00	2.22	—	—	—	2.54	4.76	3.20	100.00
70	Glass pot-clay, From Coblentz, Germany	18.35	15.66	6.84	40.85	1.20	53.03	54.23	0.63	traces	—	0.28	1.19	2.10	2.86	100.04
	FIRE-CLAYS FROM FRANCE.															
71	Fire-clay, Bollene, Department de Vaucluse...	38.20	28.19	10.50	76.89	1.15	14.95	16.10	0.40	—	—	—	2.76	3.16	3.60	99.75
72	Fire-clay, Macon, Dept. de Saone et Loire	17.80	13.10	4.30	35.20	—†	62.90	62.90	0.15	—	—	—	0.60	0.75	1.20	100.05

* Includes some FeO.

† Undetermined.

The tables of analyses above given are valuable as a basis for comparisons and for further examinations and practical tests. The analyses were all made by the same chemist and under like conditions. At present it does not appear to be possible to estimate accurately or even approximately, from the results of chemical analysis, the fire-resisting power of all clays before they have been tested in the fire. This is evident from the table. From some of these analyses we should anticipate fusion of those clays, yet they are noted fire-clays. Analyses need to be supplemented by fire-tests, and these should be of the specimens examined. A couple of preliminary fire-tests have been made with the specimens represented in the above table and some others. They were incomplete, and in the case of many specimens indecisive. Want of time since the reception of many of these, and since the analyses were finished, prevented the completion of this most interesting and promising series of investigations. The first trials were made in a crucible steel furnace, at the Newark Steel Works. The clays were cut in the form of tetrahedrons, seven-eighths of an inch on a side. The clays as they came from the pits and mines, well-dried at summer temperatures, were used in all cases where they could be cut easily and with regularity. The hard clays, as those from coal formations, were pulverized and moulded into the desired shape. All were put in a graphite crucible, and set in a steel furnace, and exposed for *one heat* (about four hours), at least up to the melting point of hammered steel. Among the specimens thus tested there were several pipe, saggar, stone ware, yellow ware, and alum clays. These were all more or less fused. Some of them melted down to flattened buttons; others were rounded considerably. Some fire-clays were partially fused, others were sharp and true, as at the outset. As far as it is possible to generalize, the clays containing much oxide of iron and potash together, were fused. The iron, when it exceeds 2.5 per cent., appears to be more detrimental than the potash. Nearly all of the more sandy clays were slightly fused. The rich fire-clays of Wood-

bridge, the Raritan river banks and South Amboy remained unaffected—not even glazed. The Missouri and the more noted British, French and Belgian clays also stood well.

METHOD OF ANALYSIS FOR FIRE-CLAYS, FELDSPARS, KAOLIN, AND FIRE-SANDS.

The method of chemical analysis adopted and pursued in the examinations of the fire-clays, *feldspars*, kaolins, and fire-sands, which are given on pages 70–76 was as follows: One gramme of the air-dried pulverized material was digested in sulphuric and hydrofluoric acids until the silica was completely dissipated; the residue was dissolved in hydrochloric acid (a few drops of nitric acid being added to oxidize the iron), and the alumina, sesquoixide of iron and titanic acid were precipitated by ammonia (in some cases by acetate of ammonia). In the filtrate the lime was precipitated by oxalate of ammonia, and weighed as carbonate. The filtrate from the lime was divided into two equal portions. In one of these the magnesia was determined by precipitation by phosphate of ammonia. The second portion was evaporated to dryness and heated to drive off the ammoniacal salts. The residue was dissolved and chloride of barium was added to remove the sulphuric acid, and, then caustic lime to remove the magnesia. The liquid was boiled and then filtered. To the filtrate, ammonia and carbonate of ammonia were added to remove the chloride of barium and lime; the liquid was filtered, evaporated to dryness, and the ammonia salts driven off by ignition. The potash was precipitated by bichloride of platinum and weighed as potassio-bichloride of platinum. The alcoholic filtrate was evaporated to dryness, the platinum compound decomposed by heating to redness with oxalic acid; treated with water; filtrated; a few drops of hydrochloric acid added; evaporated to dryness, and weighed as chloride of sodium.

A second sample (one gramme) was treated with hydrofluoric and sulphuric acids, as before, and then ammonia added to precipitate titanic acid, alumina and oxide of iron. This

precipitate was reserved for the determination of the titanic acid. The filtrate was treated as before for the determination of the potash and soda, as duplicates.

A third sample was fused with carbonates of potash and soda; the fused mass treated with water; hydrochloric acid added in excess; evaporated to dryness to render the silicic acid insoluble; treated with dilute hydrochloric acid; heated, and then filtered for the total silicic acid. This weighed determination was checked by the difference in the analysis by hydrofluoric acid. The alumina, oxide of iron and titanium were precipitated by ammonia as in the first sample. Lime and magnesia were also determined as before (duplicate determinations).

The precipitate in the second sample, reserved for the titanium determination, was treated with a solution of caustic potash and heated, to remove the alumina. The insoluble portion, consisting of oxide of iron and titanic acid, was collected on a filter, burned, fused with bi-sulphate of potash, dissolved in water, and saturated with hydrosulphuric acid gas, to reduce the iron oxide. The liquid was filtered and boiled; the titanic acid was precipitated and collected on a filter, then burned and weighed.

For the determination of the quartz the clays were digested in the sulphuric acid, and the liquid filtered. The insoluble matter on the filter was burned and weighed as a duplicate of the total silica. This insoluble matter was then boiled in a solution of potash, and the undissolved residue weighed as quartz. These determinations were duplicated by the same method.

The moisture or hygroscopic water was determined by heating over a water-bath, and the loss at 212° F. (100° C.) taken as its amount. The samples were then heated to redness, ignited, and the loss noted as combined water. In most of the dark-colored clays there was some organic matter.

In a few analyses this was estimated; in others the combined water includes very small amounts of organic matter.

The iron was determined by volumetric analysis, using the method by photo-chloride of tin.

TERRA-COTTA CLAYS.

In the manufacture of terra-cotta in England an important clay has long been the potter's clay of North Devon and Dorsetshire, the analysis of which, by Weston, is as follows:—

North-Devon.

Alumina	29.38
Silica	52.06
Lime	0.43
Magnesia	0.02
Iron oxide	2.37
Potash	2.29
Soda	2.56
Water combined	10.27

Dorsetshire

Alumina	32.11
Silica	48.99
Lime	0.43
Magnesia	0.22
Iron oxide	2.34
Potash	2.31
Soda	2.33
Water combined	9.63

Each of these clays contains a small amount of alkalies. The clays of the coal measures, technically known as the "fine clays," are also much esteemed for this purpose.

In the north of England and in Scotland, the purest lumps of fire-clay, selected by their color and texture, are used by themselves in the production of terra-cotta; but the concerns of Mr. Blashfield of Stamford, and Doulton and others near London, produce a body of much better texture by a careful and thorough mixture of clays.

It requires greater care, and is slightly more expensive for labor: but these are small considerations in comparison with the increased compact, homogeneous and better vitrified body which results from using a mixture of clays.

The precise combination of clays varies with the appearance desired for the terra-cotta; sometimes it is a light cream, or a soft buff color; at other times it may be a cherry-red, or a hard brownish-red color.

A partial vitrification of the mass is desirable in the production of terra-cotta, as it enhances the durability of the body; and in order to achieve this, clays like the Dorsetshire are added, the small amount of alkalies which they contain acting as a flux and fusing the body to a harder consistency.

New Jersey produces a great variety of clays, and the belt of country underlaid by them extends entirely across the State, and as described by the State geologist, includes an area of three hundred and twenty square miles; while the area within which these deposits have been worked to the present time is only about seventy square miles, the actual openings of the clay beds being only a very small fraction of the last-named area.

The average depth of these clay deposits is more than three hundred and fifty feet, and the order of supersession is shown in the following table:—

		Feet.
1. Dark-colored clay (with beds and laminæ of lignite)		50
2. Sandy clay, with sand in alternate layers		40
3. Stoneware clay bed		30
4. Sand and sandy clay (with lignite)		50
5. South Amboy fire-clay bed		20
6. Sandy clay, generally red or yellow		3
7. Sand or kaolin		10
8. Feldspar bed		5
9. Micaceous sand bed		20
10. Laminated clay and sand		30
11. Pipe clay (top white)		10
12. Sand clay, including leaf bed		5
13. Woodbridge fire-clay		20
14. Fire sand clay		15
15. Raritan clay beds	Fire-clay	15
	Sand clay	4
	Potter's clay	20

These clays are one of the most important elements of the material wealth possessed by the State.

Large quantities of clays are marketed annually for making fire-brick, pottery, terra-cotta ware of all kinds, tiles, retorts, crucibles, facings for wall-papers, etc.

The average price per ton is four dollars, and the average aggregate production of fire-clay alone, in its crude state, exceeds one and a half million dollars.

New uses for clay of this character are being developed all the while. The New York Terra-cotta Lumber Company has established large works at Perth Amboy for the manufacture of lumber by mixing resinous sawdust with the wet clay, which is left porous after the burning, by the sawdust being consumed.

In speaking so highly of the terra-cotta clay of New Jersey, we do not mean to be understood that it is suitable for use without any mixtures or other special preparation, as no terra-cotta clay can be so worked with safety; neither should the terra-cotta clay be confounded with fire-clay, the requirements for which are different; but that of New Jersey is also one of the best in this country, or in the world.

The body of the clay which has been described is best developed at Woodbridge and Perth Amboy, and is practically inexhaustible; and although its presence has been known for nearly, if not quite, two centuries, its employment for the production of architectural terra-cotta is of but very recent years.

It is conveniently situated between the large and wealthy cities of New York and Philadelphia, and being contiguous to the seaboard, and in easy communication by rail with all the developing cities of the country, this section should become to us what the Staffordshire district is to England.

The color of the rich New Jersey clay, denuded of the soil and often exposed, varies in shade from a light cream-color, almost white, to a soft buff, and sometimes the clay will be of a dark-red color owing to the abundant presence of the oxide of iron, a very light trace of which impregnates all the clay in the circumjacent region.

The red clays containing oxide of iron in abundance are used

only when it is desired to give the terra-cotta a deep-red brick color, which is sometimes done for friezes, panels, tiles, and other architectural requirements.

For a long distance the way between Woodbridge, Perth Amboy and New Brunswick is marked by many hollows and excavations which are sometimes of great depth. From the bottom of these, winding wagon-roads lead through banks of clay in which large gangs of laborers are regularly at work digging material to be used in the production of terra-cotta and fire-brick, and removing that which is unsuitable for these purposes.

The surface of the country is undulating, and is but thinly settled, and often a heavy growth of birches, maples, and young pines spreads over it, giving no indications of the riches it conceals, for underlying it is one vast bed of terra-cotta clay, which for fineness of texture and plasticity has no equal in the world.

In applying the term plasticity to this clay, we do not mean it in the common acceptance of that term; but in addition to the quality of receiving and giving form, that also of retaining it, not only while it is being moulded, but in that most trying time to all clays, which is the period that it is yielding its chemical water, "going through the sweat."

It may not be generally known that all things made of moulded clay, although they may appear to be perfectly dry when they go into the kiln, again become softer and almost as plastic as they were when first moulded, and it is this stage of burning that is so destructive to form in the production of artistic and architectural terra-cotta. In describing this critical period in burning, we have used the common parlance of the laborers employed about kilns, for two reasons, the first being that there is no technical term applicable to the same condition of things, and the second is that "going through the sweat" is a most accurate and literal description. Should the adobes or sun-dried bricks of Egypt, which have been exposed to the influences of that moisture-extracting climate for more than three

thousand years, be placed in a kiln and burned, the result would be the same; they would "go through the sweat" and become soft and plastic before they were burned into hard bricks.

The mechanical water has been extracted from them, but the chemical water contained in the clay has never been driven out by burning. The adobe before burning could be soaked in water, and in a few hours it would be just as plastic as it was when first made, thousand of years ago, but after burning its plasticity is forever lost.

The vitrifying ingredients usually added to the terra-cotta clays are pure white sand, old pottery, and fire-bricks finely pulverized, and clay previously burned, termed "grog;" these are employed in various proportions, sometimes amounting to nearly thirty per cent. of the mass.

The alkaline salts contained in the clays yield an efflorescence, which acting upon the silicates of the surface, vitrify to a greater degree the exterior of the terra-cotta, and this harder face should remain intact, and under no avoidable circumstances be allowed to be chipped, chiseled, or broken.

Almost any clay that will harden under the action of fire without cracking, providing it is free from stones, will make good common building brick: but it is not so with the making of terra-cotta.

Terra-cotta being made of hollow and larger forms than common brick, demands a material which has a minimum shrinkage in the process of drying and burning. Where the contraction is too great, the liability to crack in drying or to fire check in burning, is increased to such an extent as often to make the cost exceed the value of production.

For this reason the expert manufacturer will seek for such clays or combinations of clays as will contract or shrink as little as possible, in reaching the condition of hardness and texture which constitutes good terra-cotta.

The best standard texture and hardness for architectural terra-cotta is any good sandstone—test with sharp steel.

Terra-cotta should be gritty in texture and slightly porous. If it is vitreous, it will also be brittle. A small confined piece may sustain a great weight, but a large exposed portion is liable to fracture under climatic extremes when heavily weighted in part.

The slightly porous quality enables it to absorb enough water from the mortar in which it is set so as to remain where the mason places it. If vitreous instead of porous, it is liable to be slipped out of place before the mortar has sufficiently set of itself to hold it. It is a safe rule to use clays that will shrink only one-eighth in bulk during the conversion from plastic clay to terra-cotta, but this ratio of shrinkage must always be accompanied by such a tenacity or strength as will serve to hold all its particles together during the process, so that there may be no cracks or flaws in the final product.

KAOLIN OR CHINA CLAY.

Kaolin is the name given by the Chinese to the fine white clay used in making porcelain. It is furnished by the decomposition of granite and other rock, the constituents of which are quartz, mica, and feldspar, the mouldering or decomposition being caused by the joint action of air and water.

A much similar clay, to which the Chinese name has been given, occurs near St. Anstel, in Cornwall, a county in the southwest of England.

The kaolin of Cornwall, as well as that near Limoges, in France, and which latter clay was discovered in 1768, is produced by the decomposition of pegmatite, a granite in which there is very little of mica or quartz.

The clays which are much valued by porcelain-makers may be represented by the formula $Al_2O_3,3SiO_3+2HO$; all clays being silicates or hydrated silicates of alumina.

The term kaolin, when used by practical potters, usually means the finer and white qualities, or such as will make the grades of ware known as white granite or stone porcelain—called China clays. Such clays are found in many parts of the

United States, notably in Maryland, Pennsylvania, and Delaware. The actual quantity is great, as there are fifty to seventy-five potteries in the United States, which use from 100 to 3000 or 4000 tons per annum each. The price is governed by color and plasticity. Some clays are highly valued for their color only, others for their plastic property. The demand is large and steady for good China clays. To ascertain the value of such clays send a piece just as it comes from the earth to any practical potter. Potters test these matters by fire and water. Vessels coming from Liverpool are now bringing English clays as ballast, and they are sold at about the same price as American kaolin. Flint or ground quartz, or feldspar, or ground feldspathic rock, is largely used by potters, and is in good demand.

CHAPTER III.

MAKING AND BURNING A KILN OF HAND-MADE BRICK.

THE methods of manufacturing building brick by the hand process greatly differ in various portions of the United States, and in some parts of the country the period during which their manufacture can be conducted extends through the entire year, as in Texas; but in the colder States of the North, as in Maine, the season averages only about four and one-half months. A great variety of clays are necessarily found in a country covering such a wide expanse of territory as does ours. On account of the difference in clay found in various localities, different forms of brick machines, and also different methods of manufacturing by hand are necessary, and they vary according to the section of the country; but the method which we shall describe is the one commonly employed in the large Eastern States. The first operation in the manufacture of brick by the hand process is the

PREPARATION OF THE CLAY.

The first step in the preparation of the clay consists in removing the vegetable soil, which is carried to the "floors," which are the level places where the brick are moulded. The soil is uniformly spread over the floors to the depth of about two inches, and is allowed to remain from the close of one brick-making season till the commencement of another, and is then smoothed or "luted" and afterwards rolled and again "luted." The preparation of the clay is conducted either by drying or by wintering. The clays of Maine are commonly dried, and are not dug and wintered or "weathered," although much of the clay used in various portions of New England freezes during the winter, and when such is the case the clay is

used without drying; but the experience of practical brick-makers in the State of Maine has demonstrated that the light clay which has been weathered does not work quite so smoothly and easily as clay that has been dried. Clays, which are of a strong nature, make the best brick when they are exposed to the weather until the particles are disintegrated, and this is best effected by the action of frost, the water diffused through the substance expanding by freezing and breaking it in every direction. The clay becomes the more effectually reduced, and therefore more readily tempered and moulded, in proportion to the period for which it is exposed to the action of the frost. In the Middle States the brick-making season usually commences about the middle of April, and the first thing which has to be done, after attending to the floors, repairing the sheds and kilns, is the

TEMPERING OF THE CLAY.

Various methods for tempering clay are in use in different parts of the country, the hand-method, the pug-mill, the ring-pit, and the combined clay-rolls and pug-mill being used. The hand-method of tempering is sometimes used in country places, and the clay by this process is tempered by throwing the material into a pile, and at the same time saturating it with water. The pile of clay thus formed is termed a "soak heap," and the clay is allowed to soak for about twelve or fourteen hours, when the hand-temperer pulls down part of the "soak heap" with a hoe and thoroughly wets the portion of clay thrown down and turns it over several times with a spade, after which the clay is formed into a small cone-shaped pile. The hand-temperer then cuts through the small pile of clay with a tool termed a "slasher," and after "cutting and slashing" the clay for a short time in this way, it is again wetted and then turned over with a spade, after which it is in condition for the moulder. The usual work required of the hand-temperer is to "throw up," soak, and temper sufficient clay to make 2333 brick, and in addition he is required to wheel from the floor

and hack in the drying shed about 650 of the green moulded brick.

The method of tempering clay with a pug-mill is so well-known that it is scarcely necessary to enlarge upon it here; but a full description of the pug-mills and ring-pits and methods used in tempering clay for hand-made brick will be found under the respective sub-heads of "Pug-Mills," and "Ring-Pits" in this chapter. Before the clay is ground by the pug-mill it is placed in a semi-circular pit, and after being covered with water it is allowed to soak over night. When the pug-mill is operated by horse-power, one horse will grind sufficient clay in about six hours to make 7,000 brick.

The ring-pits employed for tempering clay have a capacity for grinding and tempering sufficient clay to make 14,000 brick. The pits are usually about two feet deep and twenty feet in diameter, and the tempering-wheel, which is about six feet in diameter, is made to revolve around the pit by means of suitable gearing, which is so arranged that as the wheel revolves it is gradually thrown from the centre to the circumference of the tempering pit, and is afterwards gradually again drawn toward the center. Ring-pits can be operated either by horse-power or by steam-power, but in works producing brick in large quantities the latter method is the one commonly employed.

The object of tempering the clay is to thoroughly mix it, and prepare the material for the use of the moulder, who must have it in a condition not too soft nor yet too hard, but in a suitable state of plasticity to be easily and solidly moulded into brick. After the clay has been properly tempered and brought into the desired state of plasticity, the next step in the process of producing hand-made brick is that of

MOULDING THE CLAY.

The moulder is the head of each moulding gang; all complaints against him, his wheeler, or his off-bearer are made to him, and he sees that any imperfections in the brick are remedied.

It is the duty of each moulder to get the moulding sand from the sand-pile and spread it out in the sun to dry; the off-bearer rakes the dried sand into a pile, and sieves it into a half-barrel, called "the tub;" after it is sieved, he wheels it into the brick-shed and covers it, so that no water can get into it.

The wheeler gathers the stones and hard lumps of clay that have been thrown out by the moulder, and wheels them to some out-of-the-way place.

It is always the custom for the moulder to get the "table, stool, and water bowl" in readiness before the first day's make of brick is produced, in the commencement of the season, on which day none of the hands in the yard do more than one-half the usual task; twenty rows of brick are made, instead of forty; but all hands are allowed and paid for a full day's work.

It is the duty of the moulder to take entire care of fifteen rows of the brick made by him, and laid out on the floor by the off-bearer; the wheeler is also charged with the care of fifteen rows, and the off-bearer with the remaining ten rows, and the fraction of a row, and the task of no member of the moulding gang is completed until the day's make of brick is safely placed in the drying-shed; and if portions are lost through exposure, from the negligence of any member of the gang, the value of such loss is charged to him, and deducted from his pay.

In addition to other work, the moulding gangs are required to keep the moulding-floors, gutters, and the bottom of the drying-shed in good condition.

The moulding is conducted in different ways: sometimes four, five, and even six brick are moulded at one time; but the usual method employed in the Eastern States and also in the Middle States is to mould one brick at a time. Light, cast-iron moulds are commonly employed in which to shape the brick. The size of the mould to be employed depends largely upon the nature of the clay used. Strong clays, because of their shrinkage, require larger moulds than weaker clays which do not shrink so much. The average dimensions of the Haver-

straw moulds are 4⅜ inches wide, 8¼ inches long, and 2⅜ deep. Before the operation or moulding commences, the laborer, called a "wheeler," brings the tempered clay to the moulder and piles it upon a wooden stand in front of him. A boy, called an "off-bearer," takes the cast-iron mould, and after sanding the interior, hands it to the moulder, who, with both hands, pulls down a portion of the clay from the stand or table, and after throwing a handful of moulding sand over the clay, works the mass into a peculiar form, called a "waulk," and he then dashes the "waulk" with great force into the mould, the bottom of which rests upon the cast-iron moulding cleat, as is shown in Fig. 1. The clay is dashed into the mould by the two hands of the moulder, and the excess of clay is then struck off with a "plane," which is a tool resembling the trowel used by plasterers, and is shown in Fig. 2, with which he strikes off the clay piled above the top of the mould. The boy or "off-

FIG. 1.

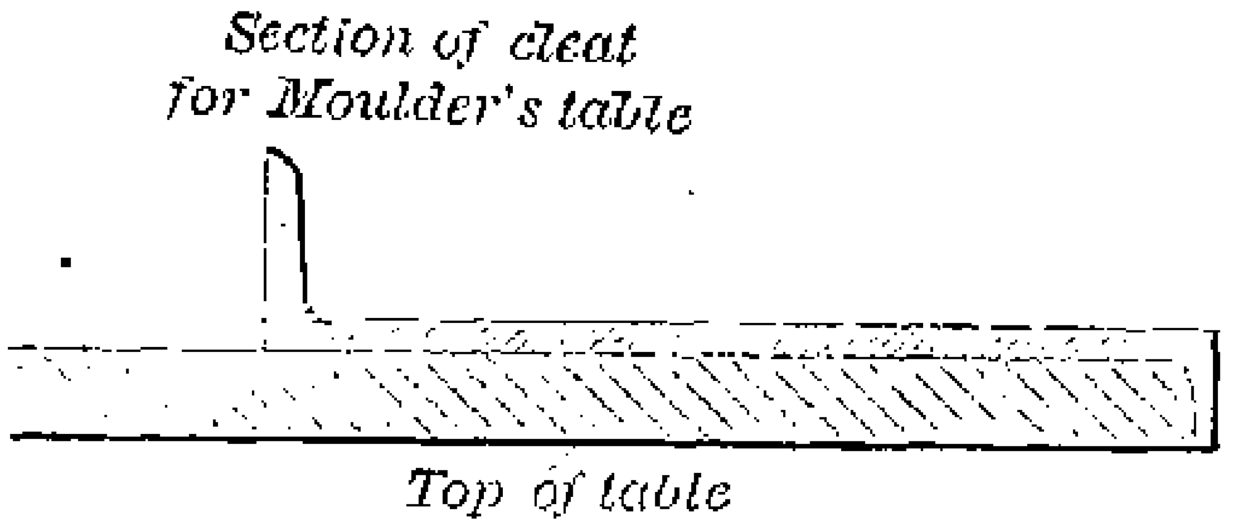
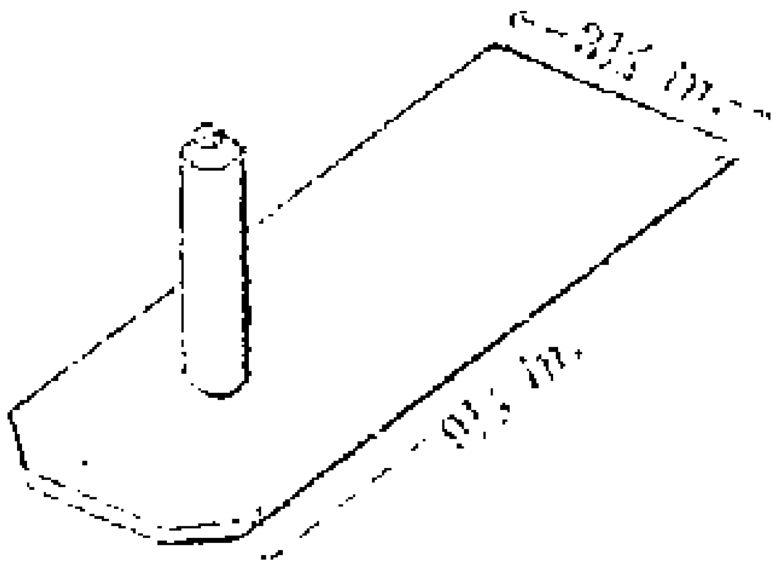


FIG. 2.



bearer" next takes the mould containing the brick, and after carrying it to the "drying-floor" he spreads it out, the brick being relieved from the mould by a gentle shock, and as the "off-bearer" returns to the moulding-bench, he cleanses the inside of the mould and especially the corners by scraping them with a knife which is carried suspended by a string from the boy's side. The mould is then thrown into a tub containing sand placed convenient to the moulder, who, during the time which has been required for the boy to carry the brick to the drying-floor and return, has moulded another brick, and the "off-bearer" takes this one and spreads it alongside of the other, and thus the work continues until the day's task has been accomplished. The brick are generally spread out until

they number 58 in each row, and 40 of these rows and a fraction of one row containing 13 brick, the whole comprising 2,333 brick, usually constitute a day's work for each moulding day. A moulding gang consists of one laborer called the "moulder," and one able-bodied man called the "wheeler," and one boy called the "off-bearer." If there is a deficiency in any of the respects in which a good brick is made, the owner's eye should be able to detect it and his brain apply the proper remedy. For instance, a moulder makes a "bible face;" a bend down in the centre will usually correct the error. If a new hand makes a perfect brick, it invariably dries crooked. It will probably be found that he "palms" his brick heavily in the centre only. Direct that he thereafter "palm" both heads. it does not matter which head first. Another man may cut a "raw face;" see that his plane is worked level instead of on edge, or possibly his water-bowl is kept too nearly empty.

Watch the off-bearing boys; see that brick are properly "bobbed" (corners and edges settled with a retouch of the mould): that they learn to line or match their brick both ways on the floor; and make any advance in wages depend on the faithful execution of these details.

It happens many times that the interests of the proprietor force him to notice points that are new to the owner of the oldest pair of hands that yet "drove a waulk." A pug-mill will temper sufficient clay for three of these gangs, and the day's work of each gang consists in moulding and wheeling to the drying shed and there hacking 2,333 brick.

DRYING.

The brick generally remain upon the drying floor for about twenty-four hours, that is, in good drying weather.

The first step in the drying of hand-made brick is to turn those upon edge that were made the day previous; if there are no indications of rain, the brick are "turned up" early in the morning, and allowed to stand upon edge, exposed to the sun, until about about four o'clock in the afternoon, when each man

"takes in his share," and carefully hacks them in the drying-shed; usually they are hacked about eight courses high on the edge and the hacks kept separate, to allow circulation of air. There is a space left between the brick of one-half inch, and a "head" or pier is built at each corner of the "rows."

If there should be indication of rain before the usual time for "taking in of the brick," and any of the brick are hard enough to handle, they are wheeled into the shed; if not firm enough, they are left to be "washed," that is, the brick on edge are again laid flat, and the rain falls upon them.

Some clays will stand this, but brick made of other clays are entirely destroyed, if not by the rain, then by the sun, as they break in half as soon as the heat again strikes them.

Brick that will stand "washing" are wheeled into the shed and set for salmon or arch brick, when they go into the kiln.

The brick having been exposed to the rain are called "washed brick;" they have a rough appearance, and are generally not much esteemed, but they make the strongest brick that come out of a kiln; and when hard-burned, they have no equal for foundation or sewer work.

After being exposed to the action of the sun for a sufficient length of time, each member of the moulding gang carries a certain number of the brick to the drying shed and hacks them upon edge. It is the custom to construct the drying-shed immediately adjoining the brick floors, and these sheds are built in a cheap manner. The usual measurement is about 28 ft. in width between the outside posts, and the height on the side adjoining the brick floors is about 4½ ft., and from these low sides the pitch of the roof runs to an incline of about 35 degrees on each side of the ridge-pole, which is supported by chestnut posts planted in the centre of the shed. The roof of the drying-shed requires to be constructed in such a manner that there will be no drip from the boards which form the roof, as the brick which the shed will contain would thereby be ruined. It is the custom in constructing these drying-sheds to put them up in a temporary manner, and the roof is formed by

extending the boards from the stringers at the sides, or low parts of the shed, and allowing them to rest upon the ridge-pole, the bottom boards being separated sufficiently far to be covered with a lap-board. It is essential that no support of any kind should be placed between the ridge-pole and the stringers at the sides of the sheds, for the water which falls upon these temporary roofs not only runs down the top of the board, but also follows the under side; and should this water in its passage meet any obstruction, like a stringer or support of any kind, before it should reach the end of the board, the water would thus drip into the drying shed and ruin the bottom of the shed, as well as the brick which might be hacked therein. The boards which form the roofs of these temporary sheds should be free from large or loose knots, and wane edges, which are liable to split and thus form drips. The board roofs over these drying sheds commonly sags in the centre, but if the boards are of good quality and free from the imperfections which we have above mentioned, it is seldom that water finds its way into the shed, or that the boards break on account of this sagging. It is customary to close the ends of the sheds with boards, but the sides are commonly left open for the free admission of air; light battened doors hung on leather hinges are sometimes used to protect the sides from driving rains. The period which the hand-made brick remain in these drying sheds is usually about two or three weeks, but during rainy seasons a longer time is, of course, required. Improved forms of drying sheds are so constructed that the roof can be made to open in sections, thus exposing the hacks of green brick to the direct action of the heat of the sun.

When brick are moulded by what is known as the "slop" method, they are sometimes hacked upon the drying floors by means of "pallets." In the "slop" method of moulding, the moulds are wetted with water instead of being sanded as we have before described. "Pallets" are flat boards, each of which holds about five or six brick, and by means of cleats at each end the green brick are prevented from being crushed by the

piling of one "pallet" above another. After the stock has been properly dried, the next operation is that of

SETTING THE GREEN BRICK IN THE KILN.

The brick having been moulded and dried, the next step is that of setting or placing them in the kiln preparatory to burning, which work is generally done by task, and usually by a force of five men, called the "setting gang," which is composed of one foreman called the "setter," and four men who bring the brick to him called the "wheelers and tossers."

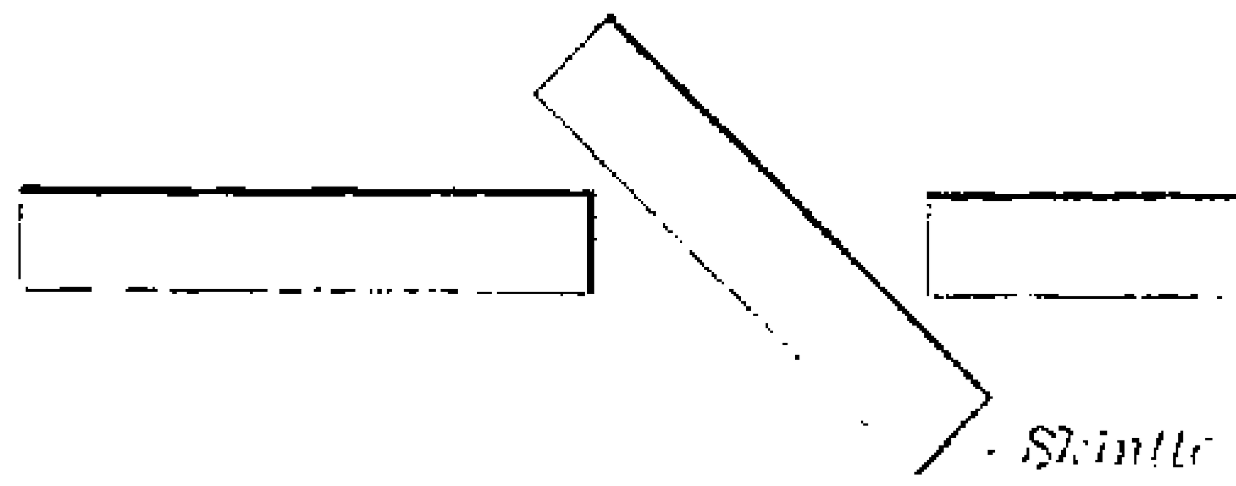
A day's work for this gang is to take 20,000 brick out of the sheds, wheel them to the kiln and toss them to the setter, who places them in a proper manner for burning.

In a kiln the first brick set are in the back arch, and arch brick in setting are divided in four classes, viz: the straight courses, pillar, hangers, and skintle brick, the names depending upon the position which they occupy in the arch.

The arch is generally fourteen courses high, the brick being set on edge and one-half inch apart; the bottom eight courses of the arch are usually called the "straight courses," on the top of which are placed the projecting six courses forming the arch, and which are called the "over-hangers."

The "pillar" brick are the ones between the straight courses, and the "skintles" are the brick set diagonally in order to tie the over-hangers together, as shown in Fig. 3.

FIG. 3.

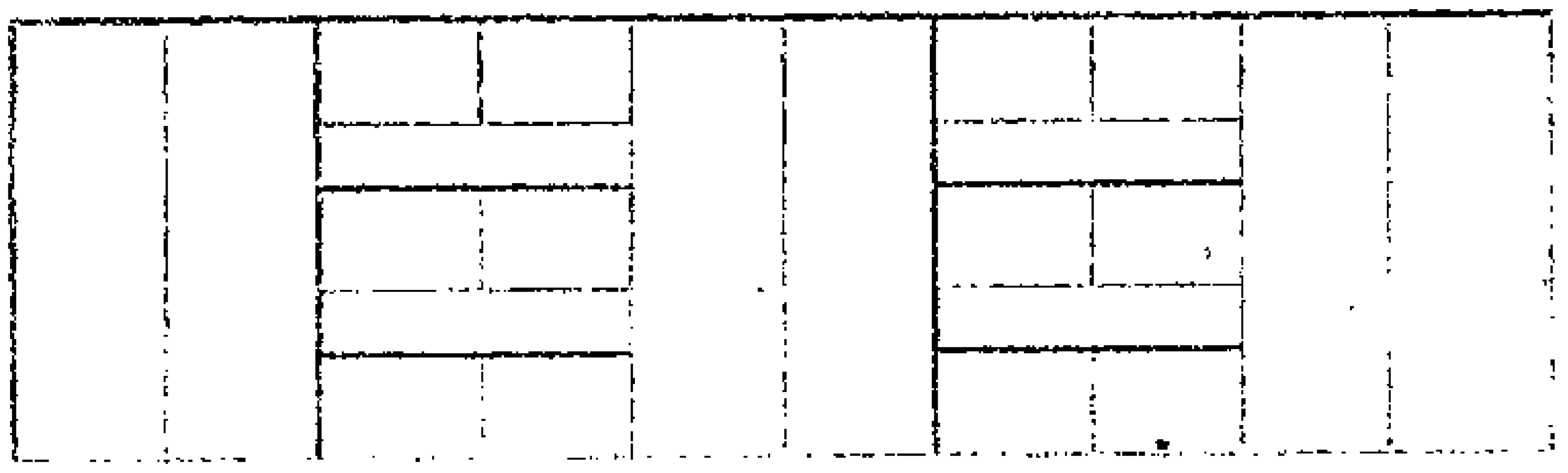


The row of brick first set on the top of the arch is called the "tie course," and the fourteen courses, including the "tie course" first set on the top of the arch, are called the "lower bench," and next fourteen courses, which usually finish the height of the kiln, are called the "upper bench." "Forty-two

high" is the way that the height of the kiln is described, and this is the usual height.

Fig. 4 shows ten courses of common brick set on the bench in the kiln, so placed as to preserve one uncrossed face to each brick. The arch, lower and upper benches, having been set, there is a brick laid flat on the topmost brick; this brick is called the "raw platting;" then on the top of the raw platting a burned brick is laid reversed way across it; this is called the "burnt platting."

FIG. 4.



It is the duty of the setting gang, in addition to placing the twenty thousand brick in the kiln, to "platt" it, and then cover up the face of the raw brick with boards on end; this process is called "facing up."

In this manner the kiln is "set out," or filled with green brick, and sometimes two, three, and even four setting gangs are simultaneously at work in the same kiln if there is a great demand for the brick.

Before any brick are set into a kiln it is plastered or daubed all over the inside face with mud in order to stop any cracks that there may be in the face of the walls, and to hold the heat when the kiln is on fire. For this work one dollar and twenty-five cents is paid for a small kiln holding one hundred and sixty thousand brick, and two dollars and fifty cents for a kiln holding one-half million of brick. The brick having all been placed in the kiln, the opening through which the brick are wheeled into the kiln, and hauled out after burning, is closed or walled up.

This opening is called a "facing," "bestowing," or "abut-

ment," and the process of walling it is termed "closing the bestowing."

The wall of the bestowing is built in two thicknesses of brick; the first or inner one is put up and "daubed" or plastered over; then the second or outer thickness is built and "daubed." Care is taken in this operation to prevent air from entering and lowering the temperature of the kiln.

The gang that puts up, daubs, and props the "bestowing" is allowed one-half day each man.

A good setting gang can commence work at five o'clock in the morning and place 20,000 brick in the kiln, and have their task completed by mid-day.

The brick having next been made and set, are ready to be burned and converted from a perishable into an imperishable substance.

BURNING.

The high price of wood in and near large cities makes it as a rule entirely out of the question to use it generally for burning brick in such localities.

The process of burning by coal is the one that we shall describe; the principle is the same as for wood, the agents employed to produce the heat being the only difference.

Brick-kilns requiring wood for fuel are flat in the bottom and paved with brick; coal-kilns have part of this pavement cut away under the portion which is to form the arch of the kiln and the place filled with grates, and under each of the grates there is a trench dug all the way through the kiln, called the "ash-pit." A space at each side of the kiln, is dug out to the depth of the ash-pits, the top covered with a slanting shed, and the space is called the "kiln shelter," and serves as shelter for the laborers and fuel while the kiln of brick is being burned. Before fire is placed in the coal-kiln the ashes made in burning the previous kiln of brick are drawn out of the pits into the kiln shelter, thrown into wheelbarrows and carried out of the way, and after fire is started in the kiln the ashes are drawn each day.

The roof over the kiln is next examined to see that it is not leaky, and then every alternate brick which was laid flat, and called the "burnt platting," is stood upon its end, this being done in order to allow the steam, or as it is called in burning, the "water smoke," to escape as rapidly as possible.

The platting having been raised, the next step is to start a small fire in the mouth of each arch, using light splintered wood, and building it up with lumps of coal; the fire should be started on the side of the kiln that will allow the smoke to be blown by any wind entirely through the arches of the kiln.

After the fires have been started in the mouth of all the arches on the windward side of the kiln, they are next made in the mouth of the arches on the opposite side.

The fires are built up gradually from each side until they meet in the centre of the kiln, and this is called "crossing the fires."

The fires should be "crossed" much more slowly for dry or damp clay machine-made brick than for hand-made brick.

When brick produced by the hand process are well dried, and there is no dampness in the bottom of the kiln or in the ash-pits, the fires can be crossed in forty-eight hours; but for machine-made brick they should never be crossed inside of seventy-two hours.

It should be noticed that the steam, or "water smoke," is freely coming out of the top of the kiln from the time that fire is put into it.

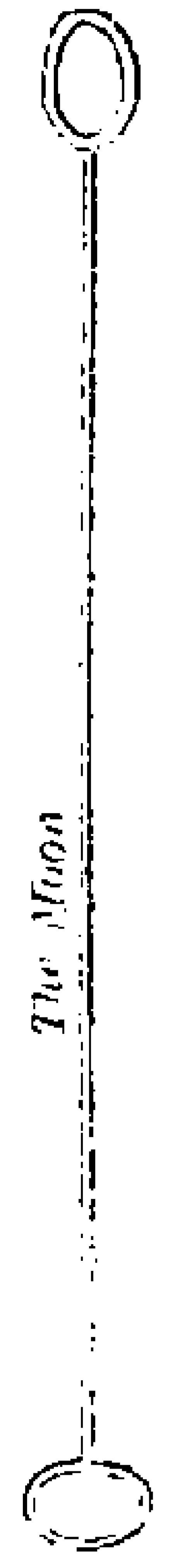
The fires are gradually increased until the fifth day, or say, in other words, the one hundred and twentieth hour after setting fire; by this time the "water smoke" or steam from the top of the kiln should have changed from a white, watery, into a bluish black smoke, and the fire should in the night-time be seen plainly coming through the top.

At this period the kiln is said to be "hot," and the brick are now ready to shrink, or as it is termed in burning, to "settle," and all the platting is put down and tightened. Care must, to this point, have been observed to increase by degrees the heat,

the firing having been gradually reduced from four hours to about two hours between fires at this stage.

The fires that the brick are now to receive are the most intense and the heaviest that will be applied to them; the oxide of iron is now to be converted into peroxide, or, as the men around the kiln would call it, "the brick are to be painted red."

FIG. 5.



Before these fires are given, a long iron rod, a little longer than one-half the width of the kiln, having a flat, nearly circular piece at the one end, open in the centre, and having an iron handle at the other end, as shown in Fig. 5, is run on top of the grates and under the fires to loosen them.

The instrument is called a "moon," and its object is to enliven the fires and to get rid of the ashes, as well as to break up the clinkers.

After "running the moon" into all the arches of the kiln, the latter are allowed to wait, or cool, for twenty minutes or so, when the arch first mooned is fired from both sides at the same time. The amount of coal thrown uniformly through each arch varies with the condition of each particular arch. An arch that is very hot is not fired so hard as one that is cooler.

The usual amount of coal thrown into each arch in these settling fires is about from thirty-two to forty shovels full for a kiln containing 200,000 brick, that is, from sixteen to twenty shovels full for each door on each side of the kiln. Before these fires are given, the doors in the ash-pits are closed, and kept closed for about five minutes after the last arch is fired. Any "cold" place in the kiln can now be detected by the black smoke not freely issuing from it, which can be seen from the top of the kiln. A few shovels full of coals are now thrown into the arches under these places.

The doors to the mouths of the arches are closed soon after the fires are crossed; if an arch is too hot, the door is opened a little, which is called "cracking the door."

It is a difficult question to determine when and how much air to admit into a kiln during the process of burning. Air in proper quantities may often be admitted advantageously above the burning fuel. After the gases are superheated in their passage through the heat chambers, then near where the heat enters the kiln proper there should be admitted as much oxygen as the heated air will absorb without reducing the heat, as it enters the kiln, below the degree required for the burning of the brick. This can be regulated by admitting more or less air and a careful observation of the heat. One skilled in burning brick knows at a glance whether he has the proper degree of heat or not. After the proper amount of air has been admitted above and below the grates in the furnace, the amount admitted below being regulated by the ash-pit door, then again near the point of contact with the brick, admit just as much as it will bear. We have then done all that can be done in this direction; the quantity is to be determined by the burner and adjusted to suit the quality of the fuel and the condition of the kiln at the different stages of burning.

The "settling fires" are given to the kiln about every two hours, unless it happens that the wind and rain keep the heat down in the arches, in which case the firing is delayed until the arches are cool enough to receive them.

After the kiln is "burned off," all the doors and all the cracks are plastered, and the kiln remains closed for five days.

If the arches are fired too hot, they will "run" or stick together. Some kilns have very high stationary roofs, others have movable roofs that slide on railroad tracks from one kiln to another: but the majority of open or Dutch kilns have only temporary roofs, which are taken off when the kiln gets "hot," which is, as has been stated, about the fifth day.

No rule can be laid down to determine when the kiln of brick has settled sufficiently, that is, sunk; the proper amount of settling is known only by experience with the clay; but for moderately strong clay, it is about seven-and-one-half per cent. of the height.

For instance, say a kiln of brick is made of moderately strong clay, and set forty-two high in the kiln, and the brick measure four-and-one-half inches in width, the total height would be one hundred and eighty-nine inches, and seven and one-half per cent. would be a little over fourteen inches. Many classes of weak clays for the same sized kiln could be settled only about seven inches, and still make good building brick.

For information as to the nature of clays the reader is referred to Chapter II., which treats of the different varieties.

The kiln which has been described in burning is the ordinary open Dutch kiln. We selected that class of kilns for describing the process because they are, unfortunately, the ones that are generally used. There are various other kinds of kilns, many of which are decided improvements, especially in the economy of fuel.

Many of the annular kilns are very economical in the consumption of fuel; but kilns of this kind have usually other disadvantages which offset the saving of fuel. The over or down draught kiln is an excellent improvement.

There are other methods for burning brick, such as by combinations of gas and air, combinations of air and gaseous fuels, and by the use of natural gas and petroleum for fuel, and other devices, which, although they are all good, require a highly scientific knowledge of heat, its mechanical action, and many other things.

The amount of coal required to burn a kiln of hand-made brick is usually about one-quarter of a ton to one thousand brick; but for dry-clay brick a larger quantity is required, the amount being about one-third of a ton to one thousand brick, which applies in both cases to the open top or Dutch kiln, but when more economical forms of kilns are employed the consumption of fuel is much less.

TOOLS AND APPLIANCES USED IN THE MANUFACTURE OF HAND-MADE BRICK.

The tools and appliances used by a hand-made brick gang, in addition to those which have been mentioned, are as follows, viz:—

One Ames's spade, No. 2, for wheeler.

One clay barrow for wheeler.

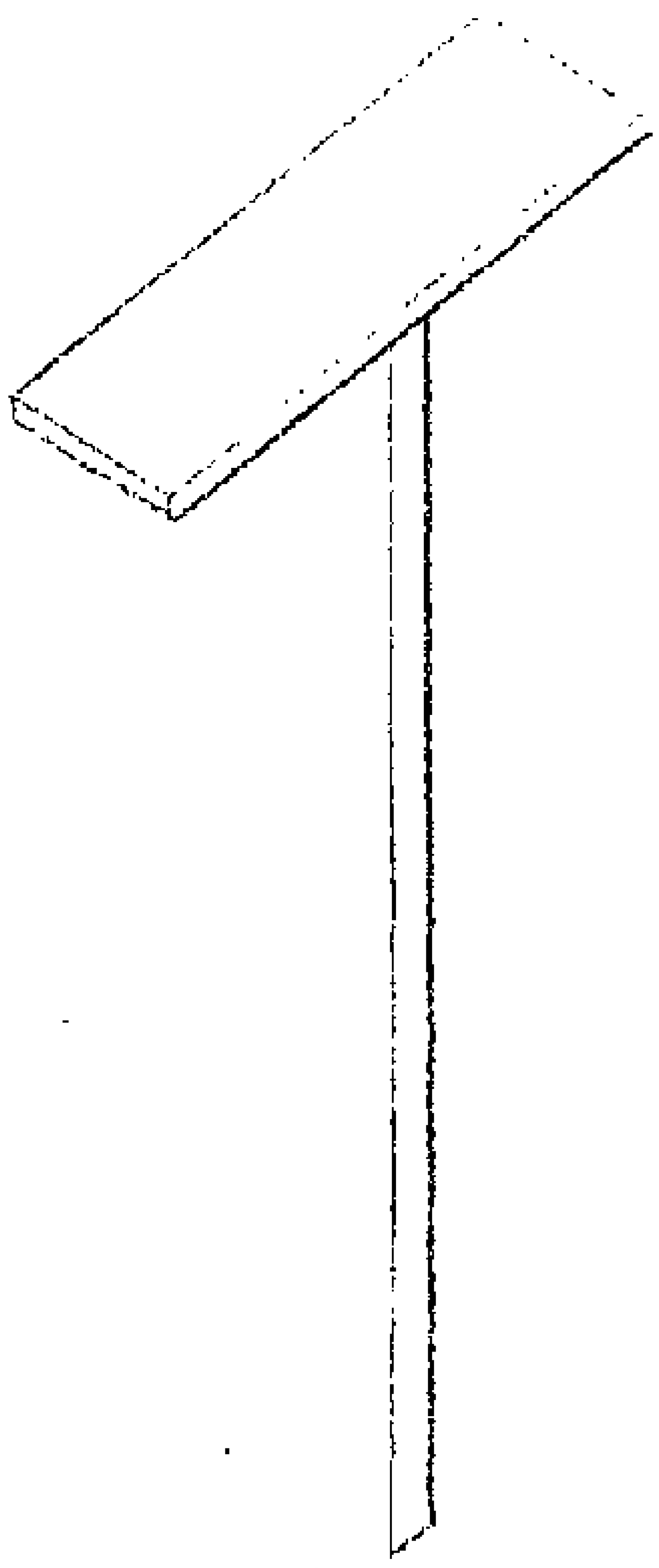
One sieve, No. 42, for off-bearer.

One brick barrow for off-bearer.

One brick barrow for moulder.

There is a tool used for scraping off and levelling the moulding floor, and levelling the bottom of the drying-shed preparatory to hacking the brick. It consists of a piece of light pine board, one inch thick, twenty inches long by six inches wide, set upright, with a long light handle in the centre. At the bottom is tacked a thin piece of steel, generally an old wood-saw blade, with the teeth turned upward, and the smooth edge forming the bottom.

FIG. 6.



Moulder's Lute

This tool is never furnished by the proprietor of the yard, it is always the private property of the moulder. The tool is called a "lute," and it is shown in Fig. 6.

The time of the men around the burning kiln is divided into periods called "watches;" a watch is two days and a night, that is, a man starts to work on a kiln, say at six o'clock in the morning; he stays that day and night, and the next day until five o'clock in the afternoon, at which time he is relieved. After resting that night, he is at the kiln the next morning, and takes another watch of two days and a night; the time made at night is counted as a day extra.

The centre of a kiln settles first in burning, after which the settling fires are put close to the mouth of the arches, no coal being thrown in the centre; the fires in the mouths are called "head fires." To enliven these fires a "short moon" is used, and it is similar to the long moon described before, and shown in Fig. 5, the difference being only in the length of the handle.

In addition to the long and short moons, another tool, called

a rake, is used; it is as long as the long moon, and has teeth three-quarters of an inch in diameter, and four inches long, set into a back of iron ten inches long, two inches wide, and three-quarters thick.

Soft coal increases in bulk after being fired, and the rake is used for levelling the high places in the fires of the arches of the kiln.

A sledge-hammer, weighing about ten pounds, is used for breaking up the large lumps of coal, fine coal being used for settling the kiln.

For each kiln hand there is required a small furnace shovel or "scoop," for firing, and in addition, two large coal shovels for general use in throwing the coal into the kiln-shelter and spreading it along in front of the arches.

A rough ladder for climbing about the kiln is also necessary, as well as two stout water buckets in which to carry the mud, or "daub," used for plastering over all the cracks which appear as soon as the kiln commences to get hot.

It is often necessary to place a barricade of boards around the kiln-shelters, and often around some part of the top of the kiln during periods of high winds, and lumber and nails sufficient for erecting this barricade should be kept on hand.

PUG-MILLS.

The pug-mill is an iron shaft with knives of the same material about eighteen inches long, two and a half inches wide, and three-eighths of an inch thick, extending from the shaft in four directions, but so placed that one does not follow directly under the other. To trace the knives around the shaft would be like following the thread of a screw. At the bottom of this shaft, and all on the same level following consecutively are four broad, curved pieces of iron, called sweeps, pressers, or pushers, which terms are synonymous, and their use is to force the tempered clay through an opening near the bottom, in the side of the cylinder or box inclosing the pug-mill.

Sometimes the casing which incloses the pug-mill is made

square and of wood, two inches thick usually, leaving the clay to pack into the square corners; at other times the cylinder is formed of iron, cast in sections and bolted together. In the Southern States the entire arrangement of upright shaft, knives, and pressers is more often called a "hopper" than a pug-mill.

The well-known manufacturers of brick and tile yard supplies—The Frey-Sheckler Co., of Bucyrus, Ohio—through whom all the tools and appliances named in this chapter can be ordered, make four regular sizes of improved pug-mills, also special sizes of pug-mills designed to suit any yard devoted to the manufacture of building-brick, fire-brick, terra-cotta, or tiles.

Mr. Alfred Hall, of Perth Amboy, N. J., has invented an improvement in the construction of pug-mills used in the manufacture of brick, terra-cotta, fire-clay wares, and pottery, the novelty of which consists in the construction and arrangement of parts in regard to the vertical revolving shaft and the blades or knives.

This invention consists in a peculiar blade or arm (shown in perspective in Fig. 8) and a shaft having a special and peculiar mortise, into which the arm or knife is secured.

Fig. 7 is a vertical central section; Fig. 8, a perspective detail of one of the arms or knives; Fig. 9, details of the parts separated, showing their relative formation.

A is the vertical shaft, to be placed in any suitable cylinder for holding the material to be operated upon. It is supported in position by the framing, so that it can be readily revolved. It has formed in it a series of cross or horizontal mortises, *B*, each adapted to hold the tenon *D* of the blade *C*. Each mortise *B* has its upper side made on a horizontal line, while its lower surface, *b*, is inclined downward from the outer end inward to or nearly to the centre of the shaft, thus giving to the mortise the shape or form in its vertical width of a half-dovetail. The tenon *D* of the blade *C* is made in form corresponding to the shape of the mortise *B*—that is, its under face, *d*, is cut away so as to give it an upward incline from the outer end to the inner end of the blade proper, and its outer end is made of

such size that it will just fit and enter snugly into the mouth or outer end of the mortise. As the tenon is pushed further into the mortise it drops downward on the inclined surface *b* and away from the upper side of the mortise, and leaves a space above it, into which the key *E* is driven. When the tenon and key are both inserted the blade will not work loose, because

FIG. 7.

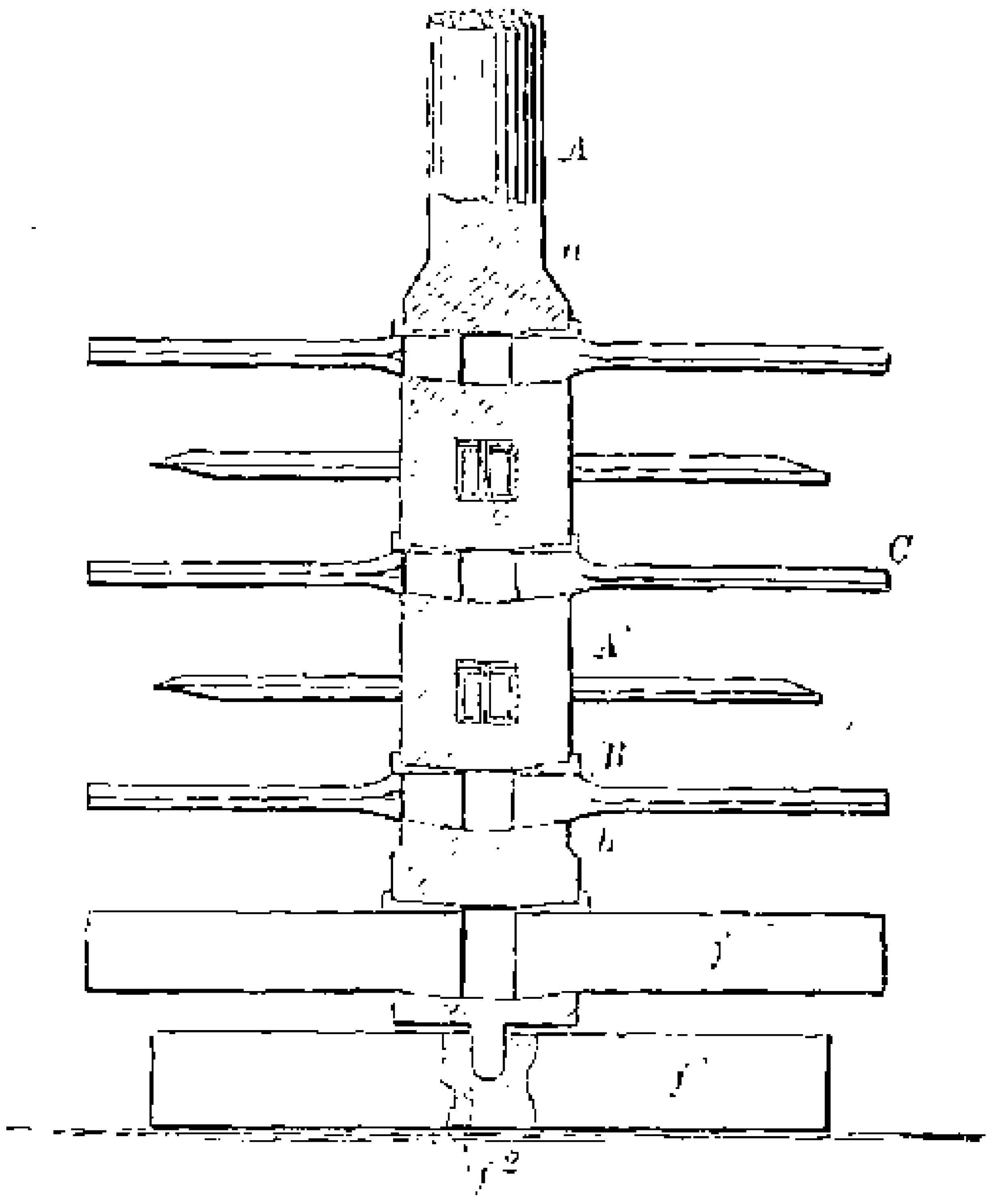
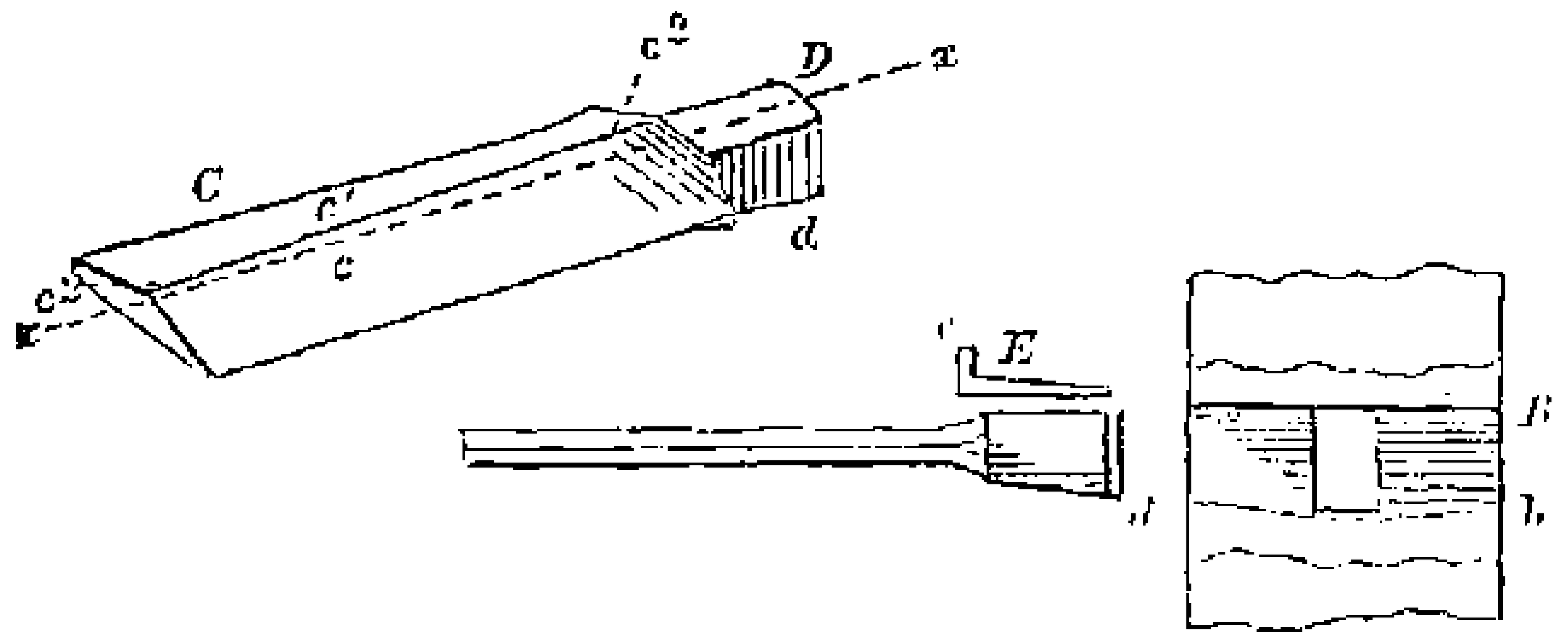


FIG. 8. FIG. 9.



the inclined surface *b* and the increasing thickness of the tenon operate to give increasing force to hold the blade against any movements tending to draw the blade outward. The material which is being acted upon will exert a pressure on the ends of the keys *E* and prevent them from working loose. The blade *C* has its under face flat or made to a horizontal plane. Its upper side is gradually thickened from the edges to a line drawn diagonally from the middle of the outer end to a point

on the inner end next the tenon, midway between the middle of the blade and the rear edge.

In Fig. 8 the dotted line x x represents the middle line of the blade. The diagonal line c^2 c^3 is the line of greatest thickness of the blade. The blade thus formed provides an upwardly-inclined front face, c, which is wider at its inner end next the shaft and narrower at its outer end. The rear face, c^1, is wider at its outer end than at its inner end. The peculiar construction of the blade gives much better results in mixing the material in the cylinder or pits. The material is sooner brought into a homogeneous mass and into the required condition for the moulds.

The key E is preferably wedge-shape, as shown.

f are the lower scrapers, which are provided with tenons of half-dovetailed form, and are secured in the shaft in the same manner as the blades C.

In case of accidental breaking of one of the blades the broken blade can easily be removed and another one substituted.

The pug-mill and cylinder inclosing are so placed that the pivot or spindle at the bottom of the mill will be in the centre of the diameter of a semicircular pit which, to contain the clay for three gangs, measures eight feet from the centre of the pug-mill shaft to the edge or brick face of the pit, which is four feet deep.

This semicircular pit is usually walled around with brick, which should be hard burned, and the bottom formed of two-inch oak planks, cut wedge-shape.

Directly in front of the pug-mill there is a fan-shaped hole or pit, which allows the wheeler to cut the clay away with a spade as it issues from the hole in the side of the cylinder at the bottom, inclosing the mill. If the pug-mill is turned by a horse, it is usual, if the clay bank is too far away to be conveniently filled with wheel-barrows, to harness the animal to a cart, and haul the clay to fill the pit, after the work of grinding has been completed, which usually requires about six hours. A long pole fixed in a yoke in the top of the shaft is the leverage by which the pug-mill shaft and knives are turned.

The pit around the pug-mill, when the clay is ground by horse power, holds usually material sufficient to make seven thousand brick; after the pit has been filled it is the duty of the temperer to see that sufficient water is let to the clay to soak it.

The clay in the pit is left to soak over night, and in the morning the temperer gets into the pit of mud, and first digs a hole in the clay, next to the pug-mill, throwing the material into the mill.

It is necessary to grind the same clay through the pug-mill several times, the first thing in the morning, before it comes to the proper degree of plasticfty for moulding; this operation is called "sizing the clay."

The temperer having secured the proper plasticity, or "size" for the clay, he continues to shovel the mud into the pug-mill, each wheeler of a gang, in turn, spading it away from the bottom of the pug-mill, as it is forced through the orifice at the base of the cylinder.

During this process of tempering, a small stream of water is continually running into a barrel sunk into the ground, near the box of the pug-mill; if some of the clay is very hard, there is used a large quantity of the water from the barrel; but if it is soft, only a small quantity of water is used.

Sometimes mud, seemingly almost slush, will be thrown into the pug-mill; but when it issues at the bottom, it is stiff and firm; when this is done, the men call it "grinding the water out of the clay;" but it is really grinding the water into the clay, and thoroughly mixing it.

The work of the temperer for the pug-mill is confined entirely to the clay in the pit, and he has nothing to do with handling any brick, as is the case with the hand-temperer before mentioned.

The pug-mills are sometimes driven by steam-power, instead of being turned by horse; in case they are driven by steam, there is a large bevel-wheel placed on the top of the pug-mill shaft, which bevel-wheel gears into a smaller pinion on a shaft keyed to a large pulley.

The pulley on the pug-mill of this character is generally about five feet in diameter, and eight inches face; if the pulley is too small in diameter, the mill is liable at times to clog and stop, leaving the belt either to slip or break.

When a machine of this kind is used for tempering clay, the pit which surrounds it can be enlarged to any reasonable extent, to meet the requirements of a yard of almost any size.

The power of the small pinion into the large bevel-gear wheel is usually about one into six; *i. e.*, the pinion makes six revolutions while the wheel into which it meshes makes but one revolution.

The quantity of thoroughly tempered clay which a mill of this kind will turn out is surprising; four men constantly shoveling clay into it cannot overstock it, if it is going at any kind of quick speed.

The speed can be regulated so as to travel at any required gait; but when it is intended for fast work, the pushers at the bottom of the pug-mill shaft must be very strong, and securely braced together with one-half inch iron rods.

The temperers who work at the pug-mills must be very able men, and thoroughly understand their business, and the nature of the clay in which they are working.

The tools used for each temperer are one Ames shovel No. 2, one hilling hoe, same as that used by the hand-temperer, and one bucket.

The pug-mill which has been described is the best thing that can be used for tempering brick or terra-cotta clays; it packs the clay very closely, and the ware made from material tempered in this manner is very homogeneous.

RING-PITS.

The next manner of tempering clay is by the ring-pits, which usually furnish clay for six gangs, and are run either by horse or steam power.

These pits are about twenty feet in diameter, two feet in depth, and commonly hold clay sufficient to make fourteen

thousand brick; they are cased around with hard-burned brick, and the bottom is usually covered with oak planks, cut wedge-shape. Hard pine is cheaper than oak, and is also used.

There is a pedestal firmly set in the centre of the pit, upon which the machinery that works the tempering wheel is placed.

For a ring-pit worked by horses, there is a long shaft of iron passing through the centre of a wheel, about six feet in diameter, called the tempering-wheel, and terminating beyond the ring far enough for two horses to be hooked to it, and have room sufficient to travel around the ring with it.

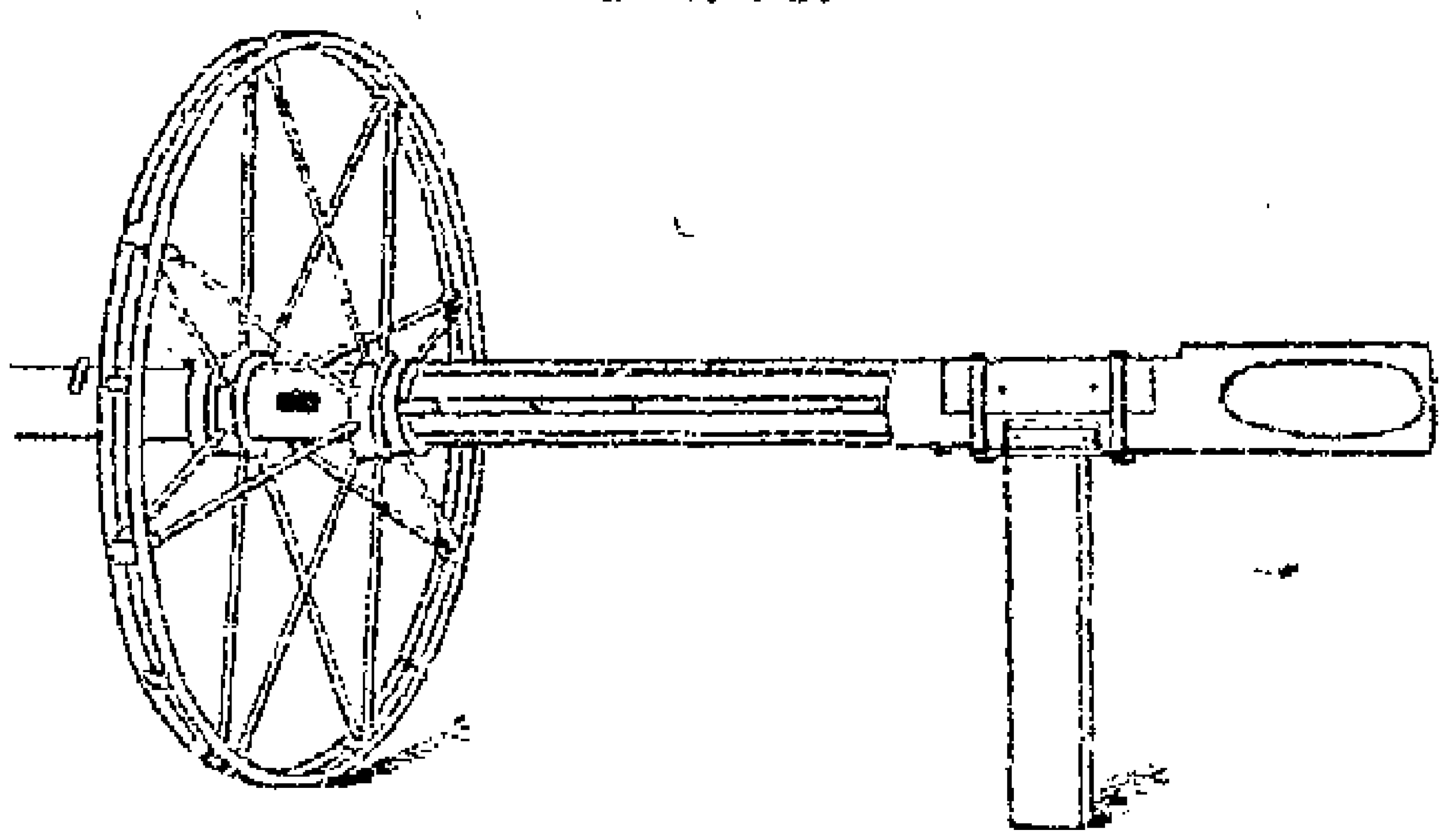
There is a gearing of wheels so arranged as gradually to push the tempering-wheel from the centre to the outer edge of the pit, while the wheel is revolving around the circle, and when it reaches the outer edge to again gradually draw it towards the centre.

In the pits using horses to work them, there is sometimes a small wheel, about one foot and six inches in diameter, and which travels in a level track around the edge of the ring, supporting the long iron shaft which passes through it.

Recent changes have been made in the wheel by placing the spokes at an angle, producing a dish in the wheel, so as to suit the circle of the pit, saving the labor of the horses; it also grinds and leaves the surface of the clay level in the pit during and after grinding. An illustration of the Raymond tempering-wheel, made by C. W. Raymond & Co., Dayton, Ohio, is shown in Fig. 10. The capacity of tempering-wheels of course depends upon the nature of the clay and also the power furnished; but the wheel shown in Fig. 10 will temper clay for 30,000 to 40,000 brick per day under favorable conditions. The open-tooth and the box racks are now in use; the latter have the cogs placed on the inside around the rack, a rib on the top side placed lengthwise, and when coming in contact with a pin placed in the bottom side of the cross-bar on the saddle, causes the rack to shift. The racks can be made of different lengths, to suit smaller sized pits, when necessary. Directions can be obtained for setting the wheels on application to the manufacturers.

When steam is the motive power, the principle of construction is about the same; but the shaft which passes through the tempering wheel does not extend much beyond the edge of the ring, and the whole machinery is attached to a vertical shaft, and on the top is a heavy bevelled gearing.

FIG. 10.



Serious difficulties have been encountered in constructing and operating machines of this class, from the fact that the power which has propelled them has been communicated through some horizontal shaft above the receptacle for the material to be tempered, which arrangement has necessitated the use of a long vertical shaft to communicate the motion of such horizontal shaft to the shaft and gear-wheels which propel the tempering-wheel. This arrangement of the parts has rendered necessary expensive, and in many cases inconvenient, frame-work to support the shafting, which often interferes with the efficient working of the machine, and is always a large addition to its cost. Another, and a very serious objection, has arisen from the fact that the pinion which meshes into the circular rack upon the upper surface of the clay receptacle has been constructed in accordance with well-known rules as to its diameter and the pitch-line of its teeth, which form of construction, it is claimed, is found defective in this particular case.

When steam power is employed for driving these machines, two of the pits are placed on the same line, the distance between the nearest points of the circles being about six feet.

There are no separate temperers for the ring-pits of either class; the driver of the horses in one case, and the engineer in

the other, let the water into the clay, and see that it is properly tempered. It requires two of these pits, of either class, to temper clay for six gangs, as it is worked out of one pit, while the other pit of clay is being tempered. The sheds, which must be maintained over the ring-pits of both classes, are much more expensive for the ones that are run by steam power than for the other class, as the timbers have to be very heavy, and well framed and braced. Sometimes clay enough to make twenty-eight thousand brick, which is sufficient for twelve gangs, is worked out of two ring-pits daily; when this is so, the pits are filled after the gangs stop work, and the clay is then tempered during the night time.

After the clay is tempered in ring-pits, it is covered with large battened panels, made of light pine wood nailed together, the object being to keep the clay moist, and prevent it from drying on the top before it is used. The laborers in the brick-yards like the clay tempered in ring-pits, as they can go in separate gangs at any time and commence work without waiting for a complement of gangs, which has to be done when pug-mills are used for tempering.

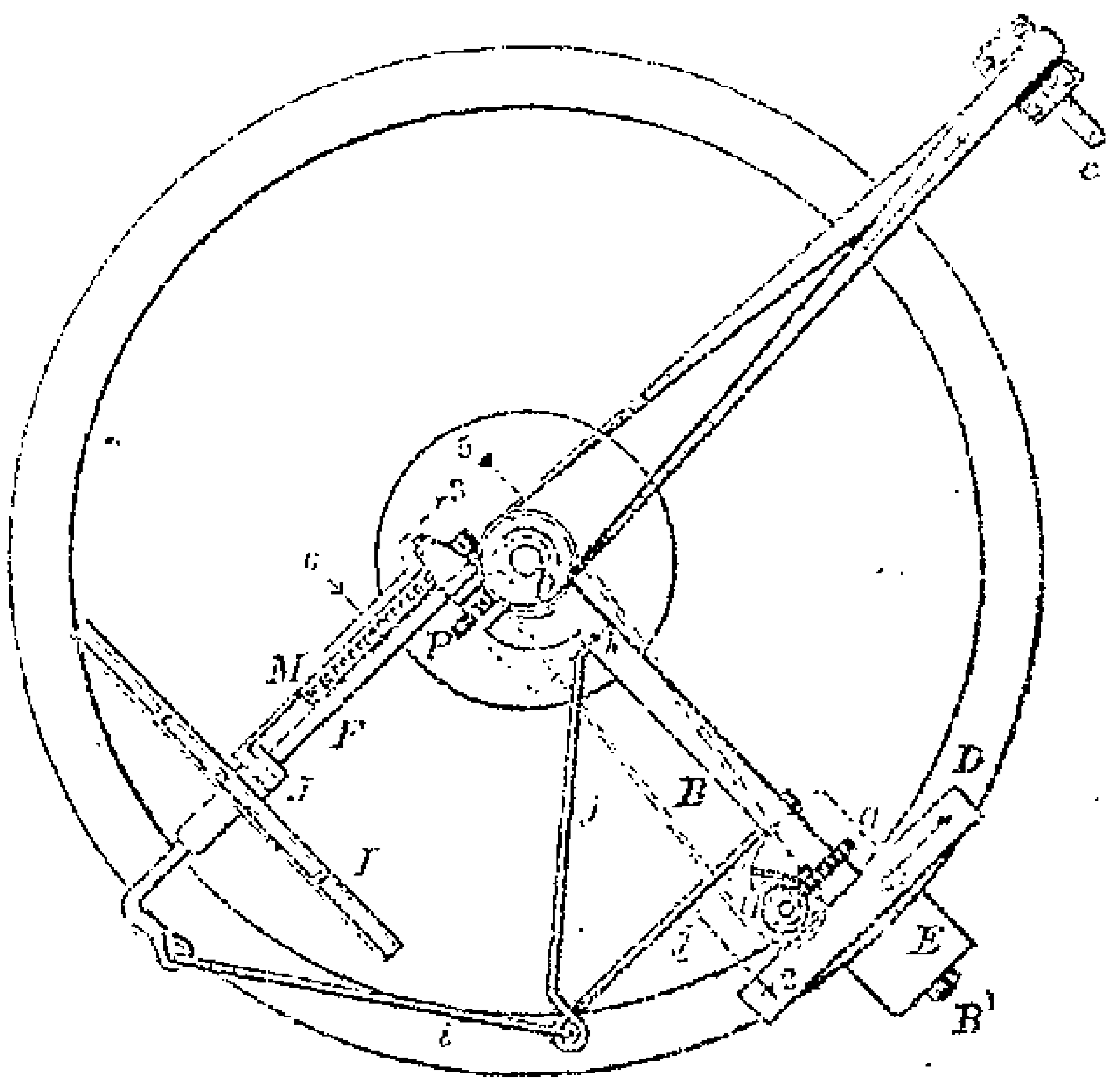
It is no unusual thing for brick-yard gangs, in the hot season of the year, to commence their task at about twelve o'clock at night, when the moon gives sufficient light, and have their work of moulding done before seven o'clock in the morning. Ring-pits facilitate this more than does any other mode of tempering the clay.

The invention of Mr. Henry Aiken, of Philadelphia, Pa., is shown in Figs. 11, 12, 13 and 14, and the main object of his invention is to dispense with complex driving-gearing, and to apply the power more advantageously than usual. A further object is also to simplify the devices by which the radial movement of the tempering-wheel on its shaft is effected, and to so construct the same that a vertical movement of the wheel is allowed without danger of throwing the operating mechanism out of gear. These objects are attained in the manner which we will now proceed to describe, reference being had to the drawings, in which—

Fig. 11 is a plan view of a clay-pit with Aiken's improvements; and Figs. 12 and 13 and 14, sections on the lines 1, 2, 3, 4, 5, 6, Fig. 11, respectively.

A is the pit, in the centre of which is a vertical standard, *a*, and to the top of the latter is adapted a loose sleeve, *x*, carrying two pulleys, *b* and *d*, the former of which receives power from any adjacent shaft—for instance, that shown at *c*—while the pulley *d* transmits this power, by means of a suitable belt to a pulley, *e*, carried by a vertical shaft, *f*, adapted to bearings

FIG. 11.



at the outer end of the radial arm, *B*, the inner end of which turns on the central post *a*. From the outer end of the arm *B* projects a short shaft, *B*¹, carrying a loose traction-wheel, *D*, the periphery of which is adapted to the rim of the pit and a worm-wheel, *g*, on the hub of the traction-wheel, gears into a worm, *h*, on the shaft *f*. (See Fig. 12.) For the sake of economy, it is preferable to make the wheel *D* comparatively light, and to increase its traction power by hanging upon the outer end of its shaft a box of clay or other cheap weight, *E*. The arm *B* is connected to the outer end of the shaft *F*, which carries the tempering-wheel *I*, by means of the link *i* and rods *j j*, and the tempering-wheel is hung to, or forms part of, a

sleeve, *J*, so adapted to the shaft *F* that it can be moved from or towards the centre of the pit, this movement being effected, as usual, by means of the double rack *M* and pinion *N*, the direction of the movement depending upon whether the upper or lower rack is in gear with the pinion. Instead of rotating the pinion *N* from a central shaft by means of spur-gearing, as usual, however, it is secured to one end of a spindle, *m*, adapted to bearings at the inner end of the arm *B*, and carrying, near its opposite end, a worm-wheel, *P*, the teeth of which engage with a worm, *S*, secured to the stem *a*. (See Fig. 13 and dotted lines, Fig. 14.)

FIG. 13.

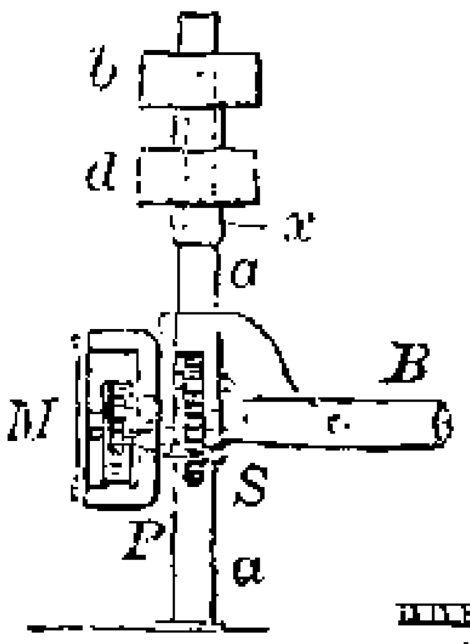
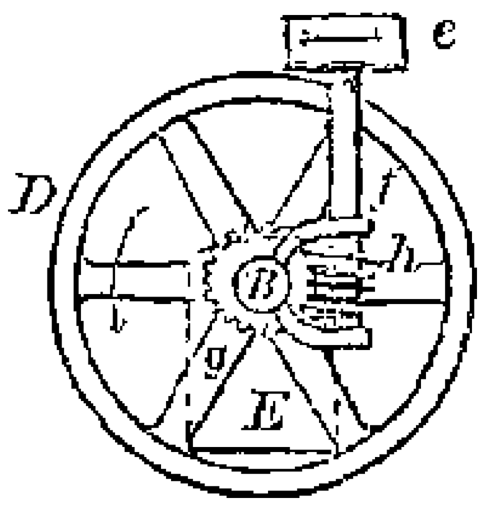


FIG. 12.



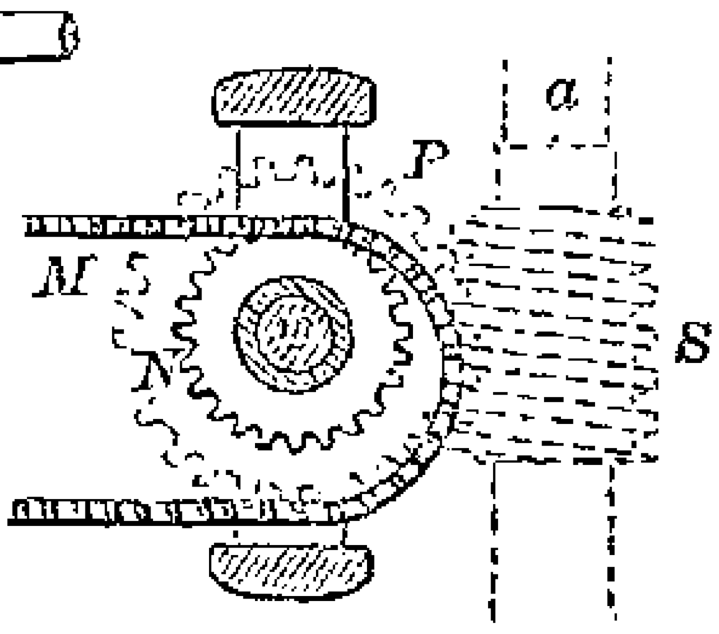


FIG. 14.

When power is applied to the shaft *f* at the outer end of the arm *B*, the traction-wheel *D* is caused to revolve, and travels around the rim of the pit, carrying with it the arm *B*, and consequently the shaft *F* and tempering-wheel *I*, while at the same time the movement of the worm-wheel *P* around the worm *S* on the central stem *a* causes the rotation of said worm-wheel and the operation of the mechanism which effects the radial movement of the tempering-wheel.

It will be evident that by the above-described arrangement the power required to effect the movement of the tempering-wheel is applied more directly, and with less loss by friction, than when this power is applied to the inner end of the tempering-wheel arm by means of gearing from a central rotating

8

shaft, while the use of the simple traction-wheel *D* at the edge of the pit obviates the necessity of locating costly and inconvenient mechanism at this point.

By the use of the fixed worm *S* on the stem *a*, and the worm-wheel *P* carried by the arm *B*, the said wheel *P* can be caused to revolve at the required speed without the intervention of the usual system of gearing, which is complicated and expensive, and causes loss of power by friction.

It will be observed in Figs. 11, 13 and 14 that the inner end of the shaft *F* is pivoted to the shaft *m*, which carries the pinion *N* for operating the rack *M*, so that when the tempering-wheel rises or falls, owing to inequalities in the bottom of the pit, the centre of movemnnt will be at the shaft *m*, thus preventing the risk of throwing the rack out of gear with the pinion, which this movement causes in machines of this class as usually constructed.

CHAPTER IV.

THE MANUFACTURE OF TEMPERED-CLAY BRICK; INCLUDING A DESCRIPTION OF THE MOST MODERN MACHINERY EMPLOYED.

GENERAL REMARKS.

THE enormous demand for brick in the large cities of the United States has vastly stimulated the invention of all classes of machinery to save labor and to produce quickly large quantities of green brick from crude clay.

The proper selection of clays as regards quantity and quality, and the suitable location, construction and economical arrangement of a brick-making plant, coupled with a practical knowledge of the art, are the corner-stones of financial success in the business of brick-making.

Cheap transportation of the machinery, building materials, and of fuel to the place of manufacture, and of the brick produced, to a profitable market, is necessary, and the question of the existence or non-existence of such facility, either by cart-load, by water or by steam, should be thoroughly and minutely examined.

After many plants for the manufacture of brick have been established and the brick made and burned, the question unfortunately is only too often asked: "Have I a suitable market for the brick which I make now and propose to make in the future?" Whether or not you have a sufficient market depends to some extent upon the kind of brick proposed to be manufactured.

If it is proposed to make common building brick entirely, it will be necessary to depend upon home consumption; *i. e.*, the brick must be sold to be used in the vicinity of where they are produced. With few exceptions, common brick cannot be

shipped a great distance with profit, as the freight on a thousand common brick is entirely out of proportion to the amount of money they represent in profits; and then, too, clays for common building brick can usually be found in abundance near the locality where the brick are to be used, so that the difference in transportation alone may be sufficient in amount to more than overbalance a good profit.

When pressed, ornamental, enameled and the finer classes of brick are to be the principal output of the works, the item of transportation is not such an important feature, for the reason that the freight is not out of proportion to the value of the product.

These facts aid in making for the pressed-brick manufacturer a market extended over a much greater extent of territory than is possible for the maker of common brick.

A manufacturer may make a good quality of brick, and with economy, and fail for the simple reason that the market at command cannot sustain the output from his yard, or from yards in his vicinity.

This has been unfortunately demonstrated in both the brick and drain tile business, especially in Indiana and Illinois.

The recent rapid progress in the art of brick manufacturing has not been accomplished without great loss of money to the pioneers in the movement, and many distressing perplexities.

The transitions from the old and obsolete method have given way to the modern brick-making machinery. To adapt appliances to work the different clays has been a most costly and harassing experiment; but at last perseverance and patience have triumphed, and the business of brick-making has reached a safe and reliable basis as regards machinery. It has nearly reached perfection in the economical manner of tempering clay and forming the brick. The tempering wheel has almost disappeared, and in its stead are a number of good grinders or disintegrators which give satisfaction.

The different kinds of brick machines may be classed under three heads, viz.: 1st, the soft mud; 2d, the dry-press; and 3d,

the stiff-mud or wire-cut. Each of them has its adherents, and each has its good and bad qualities, and each is best adapted to different clays in different localities.

Probably the three most serious drawbacks in modern machinery will be: First, a tendency to over-production. Second, the tendency to make machine-made bricks too large, which greatly increases the cost of manufacture. A suitable and proper size for brick is 2¾ inches thick, 4¼ inches wide, 8¾ inches long. Third, the inducements which machinery offers to inexperienced beginners who engage in the business and make a poor quality of brick, and consequently reduce the price.

It is not the purpose of this work to canvass and give the merits or demerits of any particular machine; but by saying what has just preceded, merely to hint at a few of the considerations which should govern those who part with their money for the purchase of either the stock produced, or for a machine itself.

The process of manufacturing brick by machinery may be divided into five stages, viz.:

Mining, tempering and preparation of the clay.

Shaping the brick.

Drying.

Setting.

Burning.

Having described the manufacture of dry-clay brick and street-paving brick in separate chapters, those systems will be touched upon in the present one only so far as may be necessary to illustrate some specific point.

MINING CLAY FOR BUILDING-BRICK.

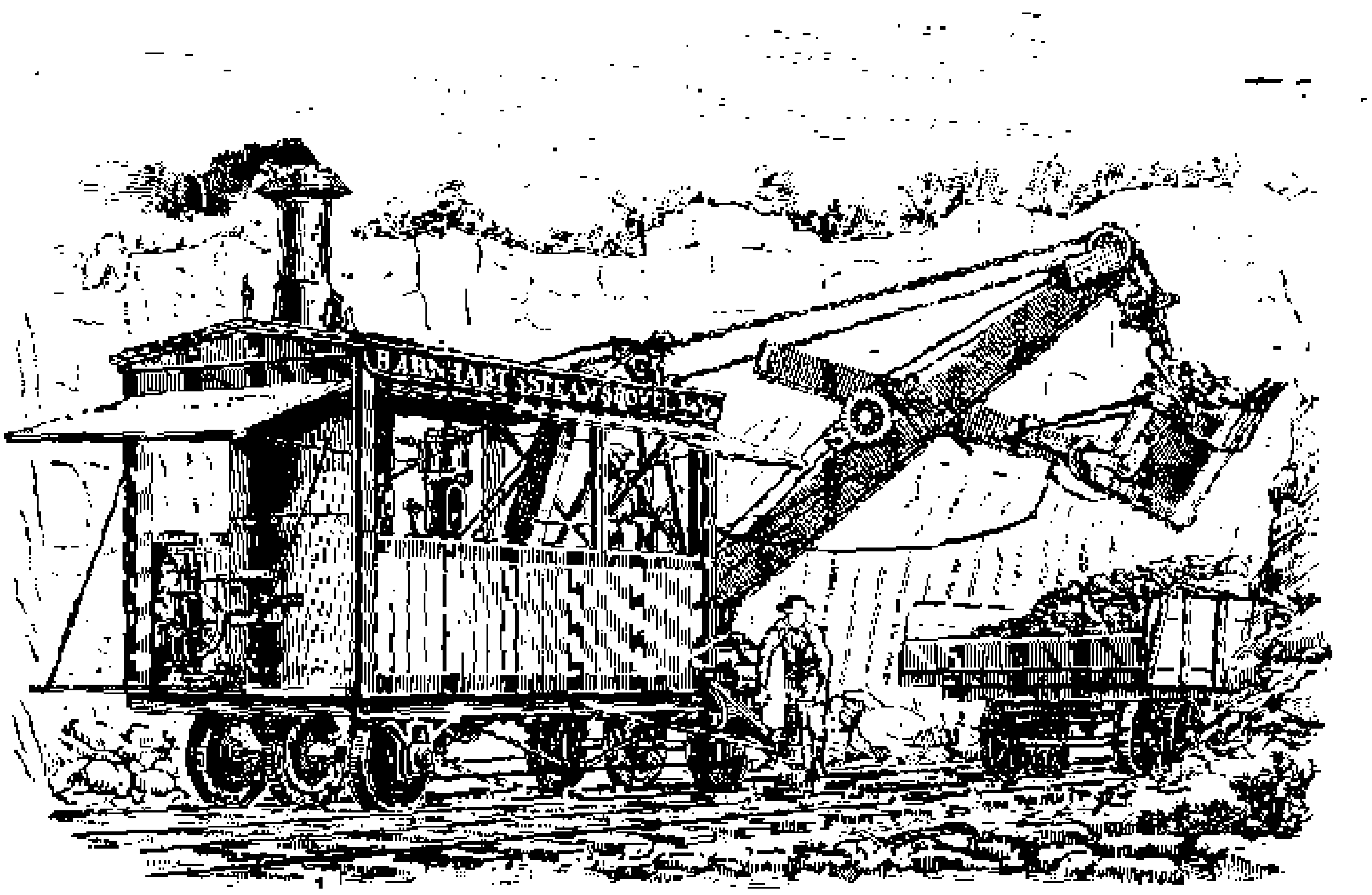
One of the great difficulties usually encountered by the manufacturers of building-brick who have established extensive works near large bodies of clay is to get sufficient clay dug, loaded, and elevated to meet the demand for the material. Along the banks of the Ohio River where the brick clay ranges

from 25 feet to 35 feet in depth, and which clay is of a tough and lumpy nature, and often runs into the wet-stiff-blue clay, it is hard to obtain, except at large expense, laborers to dig, cave, and shovel the material.

By this method the cost of placing the clay in the tempering shed averages fifty cents per thousand in the locality named, and as there is no certainty of a full supply of clay for each day's work, the result is short time and no assurance of any regular output of brick.

Men in caving are often caught in the falling bank and be-

FIG. 15.



come disabled, and it makes them wary of undertaking the "job" again, and consequently it becomes extremely hard to employ labor for that class of work.

There are a large number of mechanical clay-diggers now manufactured and designed to perform the work described, but the Barnhart steam shovel, shown in Fig. 15, will dig clay enough for from 150,000 to 200,000 brick daily, and by its use moderate-sized yards can enlarge their capacity as desired.

The steam shovel shown in Fig. 15 is built by the Marion Steam Shovel Company, Marion, Ohio, and the machine is self-

propelling and cuts the clay to a height of 18 feet, and will load 300 to 400 cubic yards per day. It digs the clay from top to bottom of bank, thoroughly mixing it. It is built on a solid frame-work upon standard gauge-wheels, and can be moved any distance backward or forward simply by laying a track. At night it can be locked up securely from intrusion by meddlers, as it has a substantial cab built over it. It is the cheapest, best, and simplest machine we know for the purpose, and gives entire satisfaction. It is operated by an engineer, one crane boy and an outside man. Formerly it took eight men to do this work. These diggers hardly pay on works making less than 50,000 brick per day. A smaller and less costly steam shovel would dig the clay for 50,000 brick daily, if properly constructed and the clay to be dug is not too tough.

The Purington-Kimball Brick Co., of Chicago, Ill., has substituted electric power for steam in operating steam-shovels used for the digging of clay, owing to the difficulty experienced in getting coal to the shovel.

Manufacturers of brick whose plants are located in the central or elevated portions of the country, can readily appreciate the advantage in digging clay, which others have who possess inexhaustible banks of clay near at hand.

Some manufacturers in the interior of the country have to haul their clay half a mile or a longer distance, and in some cases eighteen inches to two feet is the maximum depth. Even scrapers and ploughs in such instances are impracticable, and the only way to dig such clay is to turn it over, let the weather slack it, and by muscle and good strong horses and carts move it away. It takes sixty-four cubic feet of clay to make a thousand brick, and a cart having a haul of one-half mile makes about twelve loads for a day's work, and this seems to be the most advantageous method of moving clay that distance.

Manufacturers of brick having banks of clay eight or ten feet in depth often plow the clay when they have satisfactory arrangements for mixing it; but when the clay cannot be properly mixed it is better to "fall" the bank, and in that way mix the

top and the bottom and the strong and the weak clay. Where fifty thousand brick are made per day, and the clay is only two or three hundred yards away, five men and three horses and carts should be sufficient to move the clay to the crushers or pulverizers.

WINDING DRUMS AND DUMP CARS.

As steam has taken the heavy work of transporting the products of the country from the horses which formerly did the overland hauling, so it is doing now in the brick and tile factories.

The apparatus for drawing the clay into the factory by the engine, being in the first place cheaper than horses and carts and doing the work without a driver, besides not being at expense when idle, it was a natural result that the winding drum and automatic dump cars were adopted by all enterprising brick manufacturers.

To suit different demands, the Frey-Sheckler Co., of Bucyrus, Ohio, has constructed two styles of winding drums, which are self-contained in substantial iron frames, and can be operated by a cord from the clay pit or by the engineer from any point in the factory.

Fig. 16 illustrates the Friction Winding Drum which the Frey-Sheckler Co. make in three sizes, to wit: Nos. 1, 2 and 5. A machine of this kind is one of the essentials of a well equipped brick factory, for the transportation of clay from the pit to the factory. This Drum is substantially built. The frame is heavy, and is so constructed that it can be bolted to the upper part of the track timber.

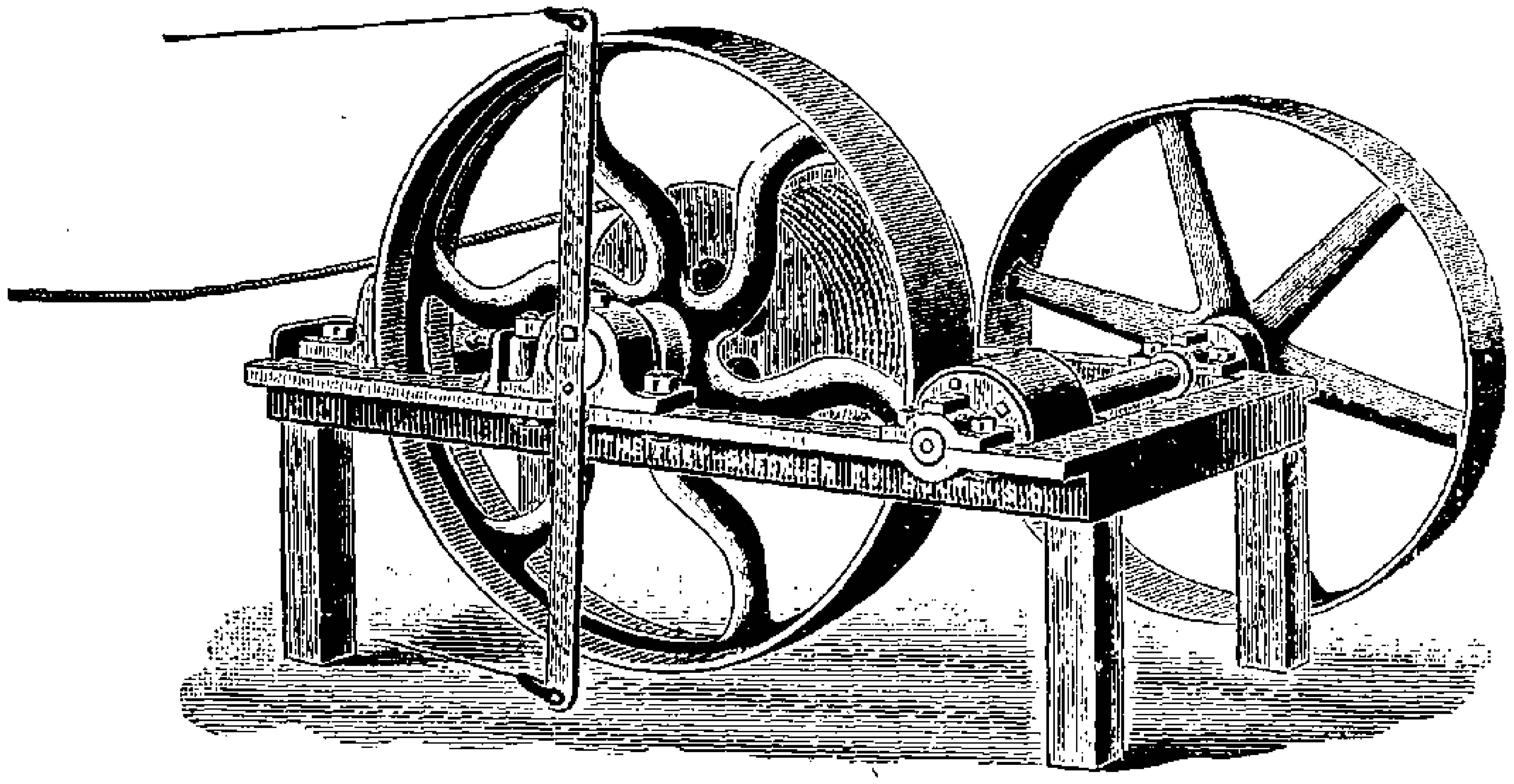
No. 1 Drum has a friction pulley 40 inches diameter and 7-inch face. The paper friction pulley is 8 inches diameter and 7 inch face. The driving pulley is 24 inches diameter and 6-inch face. Speed, 500 revolutions per minute; geared 5 to 1; weight of Drum without cable, 1,100 pounds. Drum will hold 800 feet ⅝-inch iron cable.

No. 2 Drum has a friction pulley 30 inches diameter and

6 inch face. The paper friction pulley is 6 inches diameter and 6 inch face. The driving pulley is 26 inches in diameter and 6 inch face. Speed, 500 revolutions per minute; geared 5 to 1; weight of Drum without cable, 700 pounds. Drum will hold 300 feet ⅝-inch iron cable.

No. 5 Drum is 24 inches diameter and 36 inches long inside of flanges, which are 5 inches high all around. Diameter of main shaft, 3½ inches; diameter of pulley shaft, 2¾ inches. Speed, 350 revolutions per minute; geared 5 to 1. Driving

FIG. 16.



FRICTION WINDING DRUM.

pulley is 24 inches diameter, 10 inch face. This drum will hold 3,400 feet of ⅝-inch cable. Weight of drum without cable, 4,500 pounds. Floor space required, 7 feet by 5 feet 9 inches.

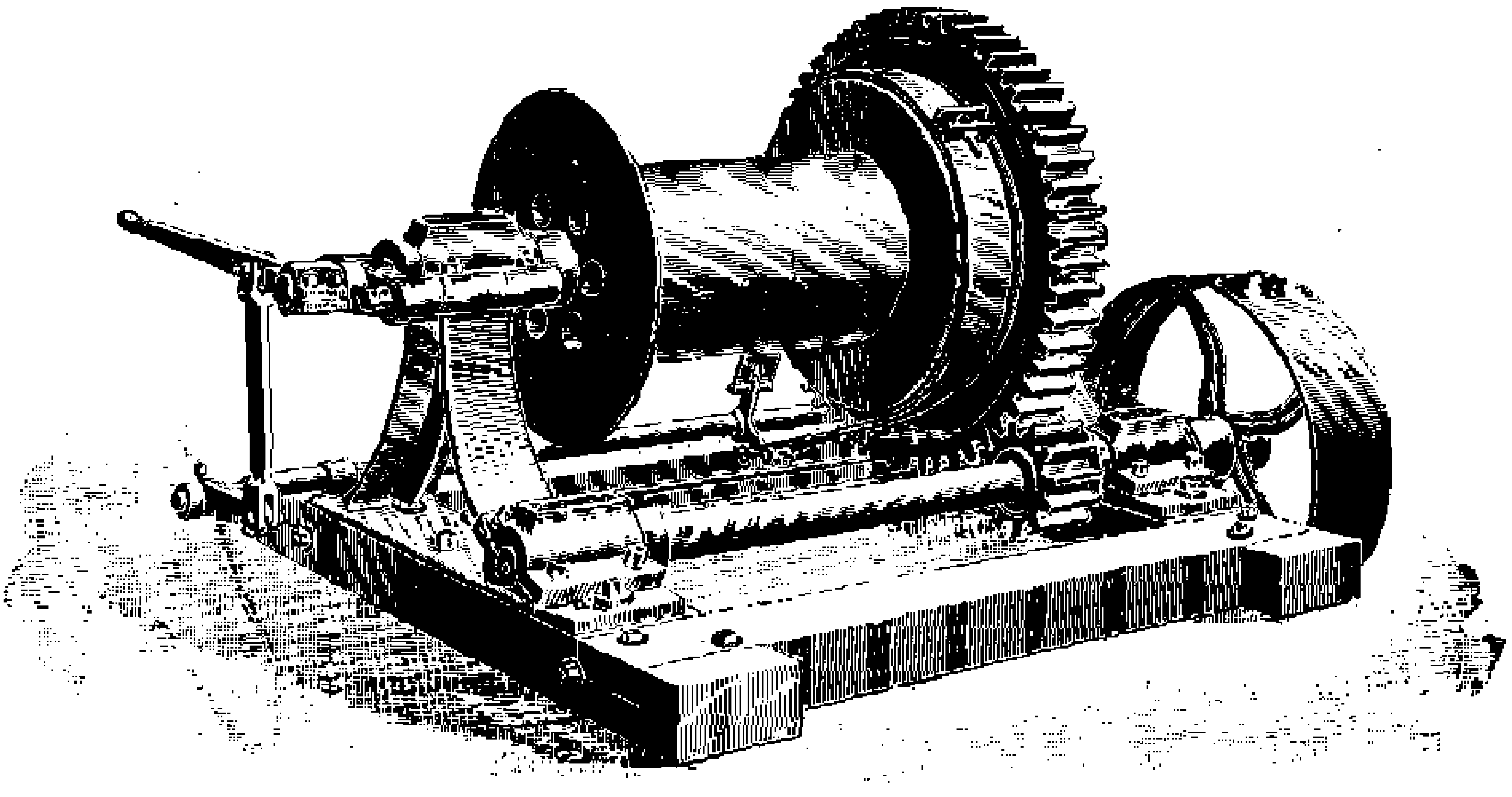
Fig. 17 illustrates the gear and friction winding drum made by the Frey-Sheckler Co., which is made in two sizes, to-wit: Nos. 3 and 4. The construction throughout is strong, simple and durable. It is not liable to breakage or derangement, and is mounted on a solid white oak frame. The drum runs loose on the shaft and engages itself with the wood friction (which is securely bolted to the large spur gear) by being forced along the shaft by means of the lever.

This lever is connected by a rod with the band brake lever.

so that both the friction and the brake levers are operated by one movement. Thus with the levers in a central position, as shown in the engraving, the drum is left free to revolve on the shaft. When the levers are forced down the brake is applied, and holds the drum or lowers the load as desired. When the levers are raised the drum is brought into contact with the friction disc and raises the load, then the brake is released. This brings it fully under the control of the operator.

No. 3 Drum is 12 inches in diameter and 24 inches long inside of the flanges, which are 5 inches high all around. The

FIG. 17.



GEAR AND FRICTION WINDING DRUM.

driving pulley is 24 inches diameter, 8 inch face. Speed, 550 revolutions per minute; geared 4½ to 1. This drum will hold 1,300 feet of ⅝ inch cable. Weight of drum without cable, 1,725 pounds.

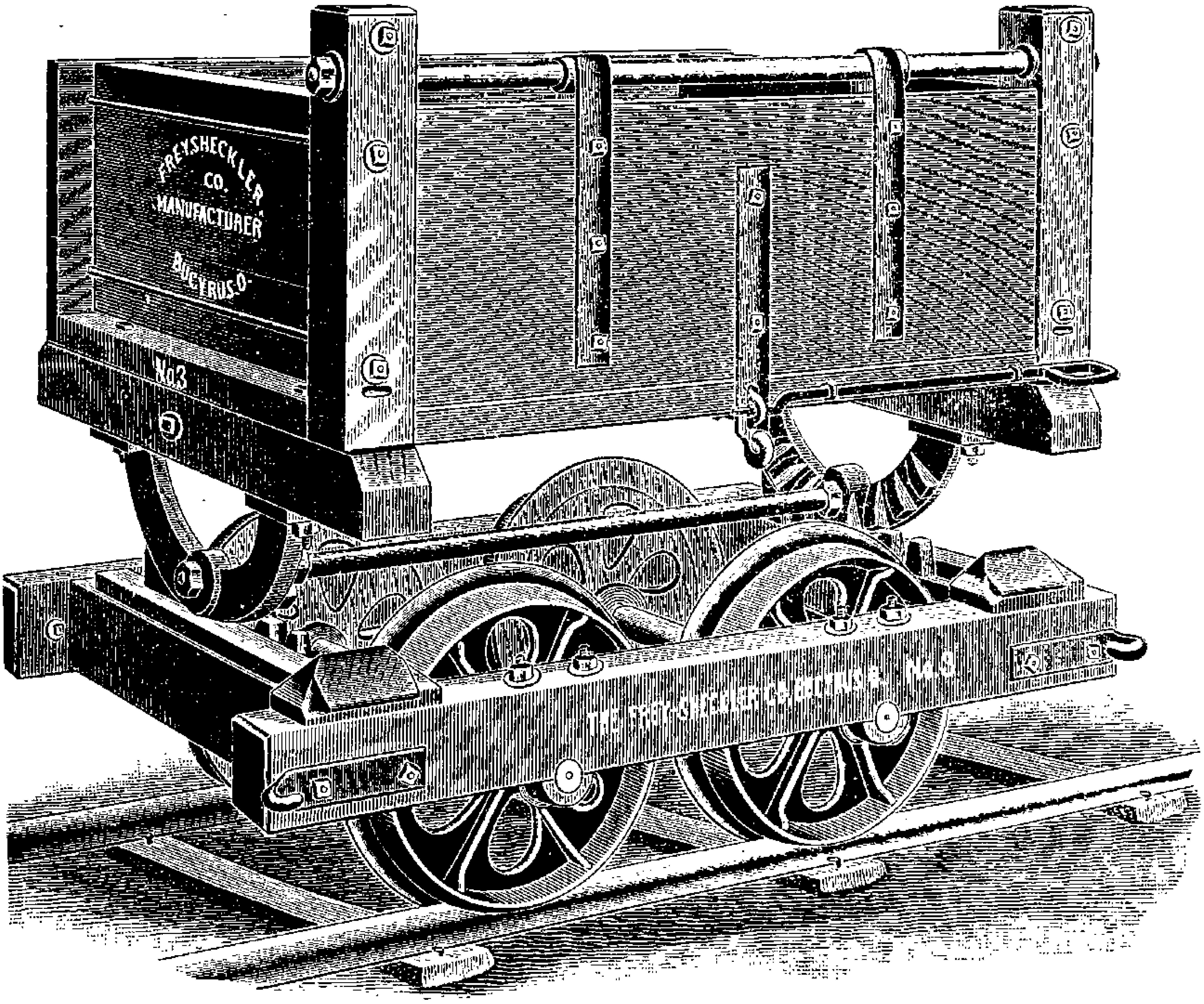
No. 4 Drum is 24 inches in diameter and 30 inches long inside of flanges, which are 5 inches high all around. Geared 5 to 1. Diameter of main shaft 3½ inches, diameter of pulley shaft 2¾ inches. Speed, 350 revolutions per minute. Driving pulley is 24 inches diameter, 8 inch face. This drum will hold

2,800 feet ⅝ inch cable. Weight of drum without cable, 3,500 pounds. Floor space required, 6 feet 7 inches by 5 feet 8 inches.

The speed of the above drums was based upon the supposition that the dump car travels six miles per hour.

Fig. 18 illustrates the Side Dumping Clay Car, made by the

FIG. 18.

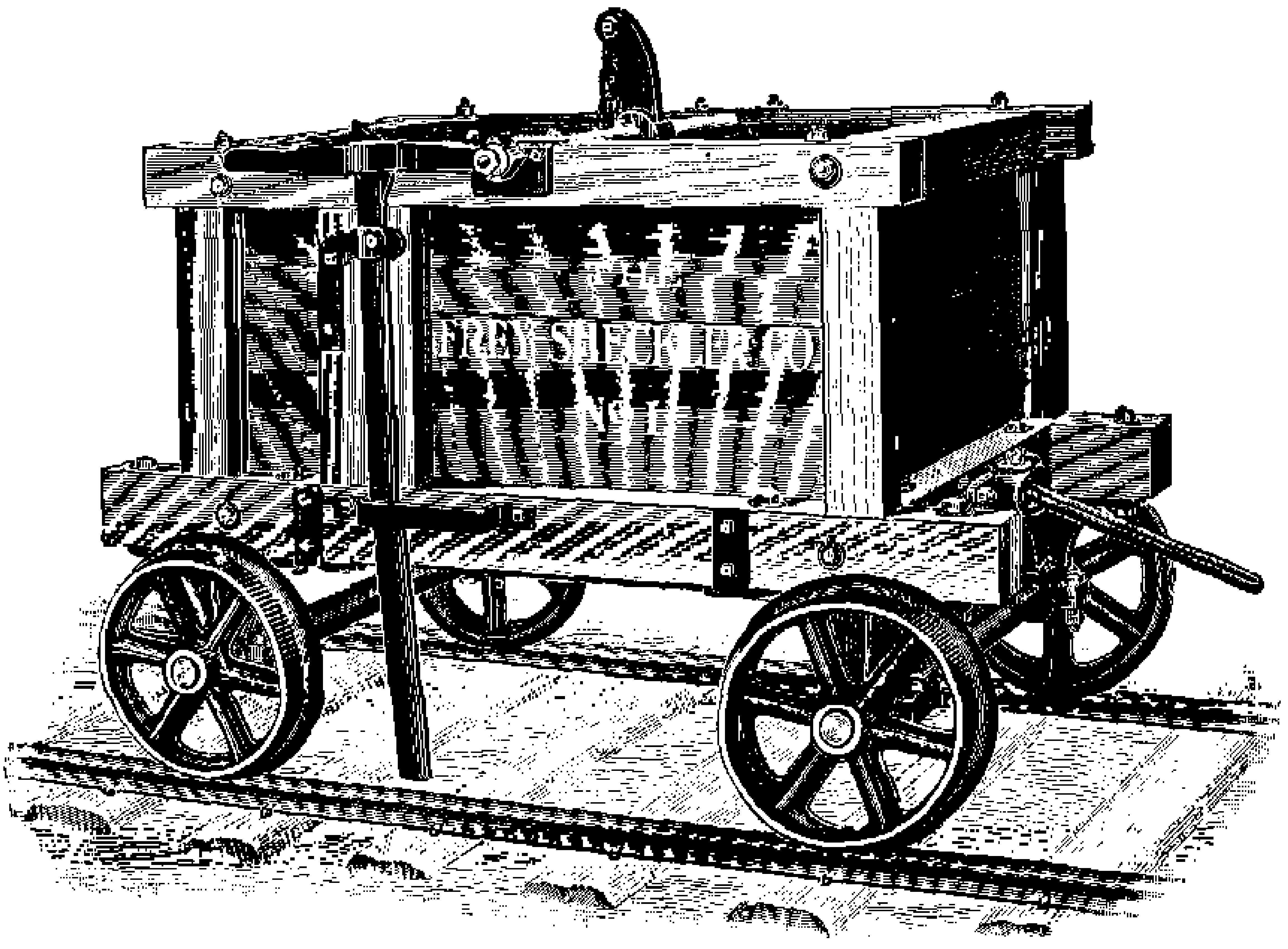


Frey-Sheckler Co. This car is substantially constructed in all parts; it is made to dump on one side only, but it can be furnished to dump on both sides if desired. The side is hinged from the top and arranged so that when the car is tilted over the catch holding the car in position is released, allowing the side to swing out at the bottom. The wheels, 17

inches in diameter, are very heavy, chilled and annealed. This car is made in three sizes. No. 3, capacity ¾ cubic yard, track gauge, 36 inches; No. 4, 1 cubic yard, track gauge, 36 inches; No. 5, 1½ cubic yards, track gauge, 42 inches.

Fig. 19 illustrates the Bottom Dumping Clay Car, manufactured by the Frey-Sheckler Co. This car is remarkably strong. The timbers are heavy and securely bolted together;

FIG. 19.



the wheels, 17 inches in diameter, are thoroughly chilled and annealed, and the workmanship throughout equal to the highest established standard. This car is arranged to dump automatically. The bottom is in two parts and hinged at the sides of the box, and held in position by two chains which are attached to an arm keyed to a steel cross-shaft which has a lever on the outside of the car, which is held in position by a catch that hangs down between the wheels near the track. A stop fastened to the track releases this catch and lets the bottom

drop, when the car runs back, and the diggers, by a pull of the lever, again place the bottom in position. The Frey-Sheckler Company make two sizes of this style of car. No. 1, capacity ¾ cubic yard, track gauge, 42 inches; No. 2, capacity 1 cubic yard, track gauge, 42 inches.

TEMPERING AND PREPARING CLAY.

In early days, for tempering clay men first spaded and then stamped it with their feet; next oxen trod, afterward the gum, later horses and wheel, finally the steam wheel took the place of horses for tempering the clay. Then in turn the steam wheel had to go, and in its stead we had rollers to break the lumpy clay, and now disintegrators and grinders to thoroughly pulverize it are employed.

The clay-crushers that are now being used commonly have smooth rollers, although almost every one of them has some device for tearing the clay to pieces. The inventors of brick-making machines have learned that something must be done in the way of preparing the clay other than by smooth rolling. The day is not far distant when it will be a necessity to put more expensive, stronger and better machinery into preparing clay than has yet been done: some device which will thoroughly pull the clay apart and open the pores.

In order to make a good brick, either soft-mud, dry-pressed, semi-dry, stiff-mud, hand-made, or any other kind of brick, the clay should be properly prepared. It should be ground very fine, whether it be ground first, dried, and then tempered with water, or whether it be ground with the water; the finer the clay is ground the better the brick will be. In the majority of cases where dry-clay brick have been found to be a failure, one of the reasons for the lack of success in their manufacture will be found to be because the clay was not properly ground.

If a good hand-made brick is desired, prepare the clay, make it smooth, work the clay thoroughly, and let the proprietor see for himself that it is prepared. In clays not ground properly, dry lumps of clay in the brick cause it to break and burst. This is proof that the clay must be properly prepared.

It is better to take the clay out in the fall, and let it be exposed to rain and frost during the winter. By so doing it is possible to burn brick 15 or 20 cents per thousand cheaper than if the clay is taken fresh from the bank; that is, by the old way of burning.

A machine which is going out of date, because it has been superseded by the modern pug-mill, is the old-fashioned tempering wheel.

There has probably never been a tempering device by which clay could be prepared so evenly, uniformly, and thoroughly, and as perfectly in every respect, as with the tempering wheel; but it costs so much more to temper clay with the wheel than by the pug-mill that the tempering wheel must soon disappear because it costs too much to prepare the clay with it.

Where there are different strata of clay to be worked, soak pits should be used in which to thoroughly mix the clays.

If there are made as many as 35,000 brick per day in a yard, the soak pits should be about 35 feet long, 12 feet wide, and 4 feet deep: put an elevator right in the centre of the pit, run a chain belt from the lower end of the pit, bringing it up on an incline, which will allow the clay to be drawn up into the machine. If the clay is of a greasy character, have a little water running which will aid to slide up the incline. There should be no trouble in carrying up clays in that way when the clay is soaked before it is put into the machine.

In making tiles or fine brick, soaking the clay a few days before using it pays, and it is necessary, in order to have brick with lasting qualities, that the material should be made thoroughly homogeneous before it is moulded.

When the clay to be employed is of the bluish variety, lumpy, rough and difficult to soak, it will pay to use a crusher, as otherwise the bricks, although strong, will be rough in appearance and often not marketable.

In clays where rock or pebbles are present or where the clay has not been thoroughly disintegrated by frost and exposure, we do not know of any better remedy than the use of the disin-

... decidedly in its favor.

The plan is sometimes adopted to temper clay by conveying it to a horizontal clay mill, into which it is fed as evenly as possible with a spray of water thrown on it, regulated to any desired quantity by a stop-cock under control of the feeder.

The clay after leaving the horizontal conveyor is next carried to the tempering cylinder of the brick machine and there receives its second and usual pugging.

This process does very well for the early spring months; but as the season advances and the ground becomes drier, many little hard lumps pass through the pug-mills without being crushed, and all bricks containing them crack in drying.

The experiment has been tried of first passing the clay between crushing-rolls, but the clay either came through in sheets which were hard and smooth and would not temper in the pug-mills, or else would adhere to the rolls and give continued trouble to clean them; and the only satisfactory solution was to use a disintegrator and pass the clay through it before conveying it to the brick machine.

Hot water tempering is not always an improvement over cold water, as it often makes some clays more sticky and difficult to dump from the moulds. Hot water does not hasten the drying of brick. After a number of experiments, in which brick made by each process were placed side by side, the difference, if any, was too small to compensate for the disadvantage of sticky moulds.

It is often difficult during the winter months to reduce hard-frozen clay to that condition necessary to make brick, as it clogs in the rolls or pulverizer and causes loss of both time and patience. A simple method for thawing clay consists, for small works, in laying down a plank floor about 8 feet wide by 20 feet long, with one end of the floor a few inches lower than the other. Then put about four rows of one-inch pipe the full length of this floor, and far enough apart to shovel between them easily. In these pipes, about one foot apart, drill holes about one-sixteenth of an inch in diameter, on alternate sides, so as to allow an emission of a jet of steam every twelve inches,

first on one side and then on the other. Connect the pipes at the highest end of the floor by a header, and place a plug in each pipe at the lower end, with a small hole in each plug to carry off the drip or condensed steam. Lastly, drive some staples down over the pipes to keep them in place, and then cover the pipes over with about 30 tons of clay, piled six feet high, fill the boiler well up with water, run the steam down to about 30 pounds pressure, turn the valve connecting the boiler with the clay pile about two turns, and leave it in that condition during the night. The next morning, under an outside crust of about one inch thick, will be found the clay in good condition for use and the frost out of it.

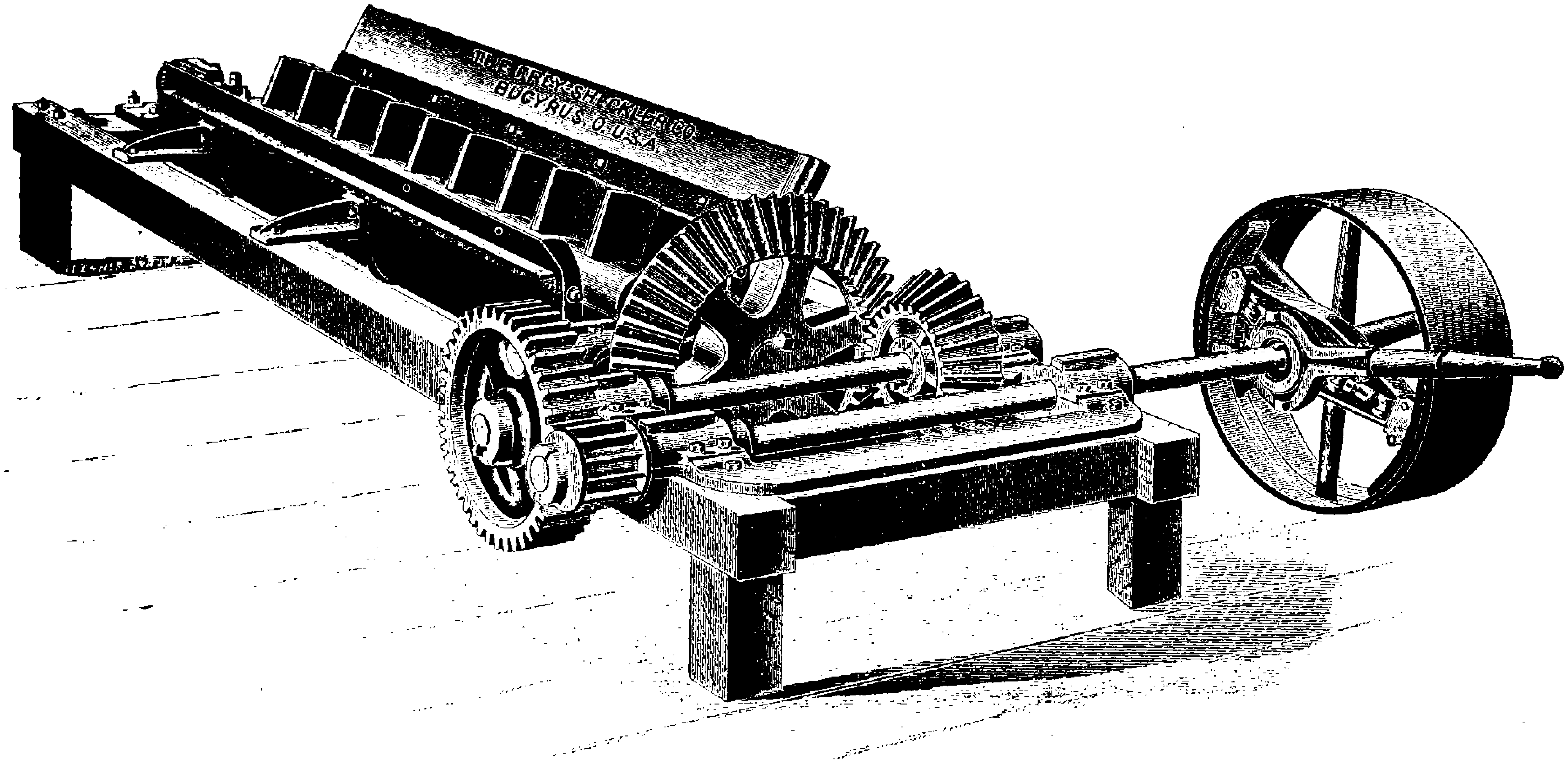
The simplicity, cheapness, and complete success of this plan make it within the reach of all clay-workers who have steam at command.

A great deal of trouble occurs often in elevating the clay to the disintegrator, or from the disintegrator to the brick machine, especially when the clay is a little wet, as it sticks fast and clogs on the belts; and oftentimes this trouble can be greatly lessened by using a canvas belt, with two chains on sprocket wheels, at the crusher and at the mill, using four-inch rollers about a foot apart to support the intervening space. One of the greatest causes of failure in using belt-elevators is having them too steep and not properly supported.

Fig. 20 illustrates the No. 1 Granulating Pug-Mill built by the Frey-Sheckler Co. This machine is built very heavy, and is 10 feet long in the pugging chamber, which is made of boiler steel ¼ inch in thickness. The shaft is hammered steel 4½ inches square. The knives are made of charcoal chilled iron. This machine is used for granulating tough, strong clays before passing to a crusher; this is a very essential feature in clays of this character. Inasmuch as the stones are liable to catch on the knives and break them, a safety pin is inserted in the driving pinion so as to prevent breakages. It also acts as a distributor or feeder for the crusher.

The clay is dumped in at the rear end by carts or dump cars,

FIG. 20.



GRANULATING PUG MILL.

and the knives tear the clay to pieces and gradually carry it along while disintegrating it, so that a constant and even stream flows into the crusher, and the rolls take it through readily. This machine is provided with a friction clutch pulley 36 inches in diameter, 10 inch face. Speed, 150 revolutions per minute; weight, 7,000 pounds.

CLAY CRUSHERS.

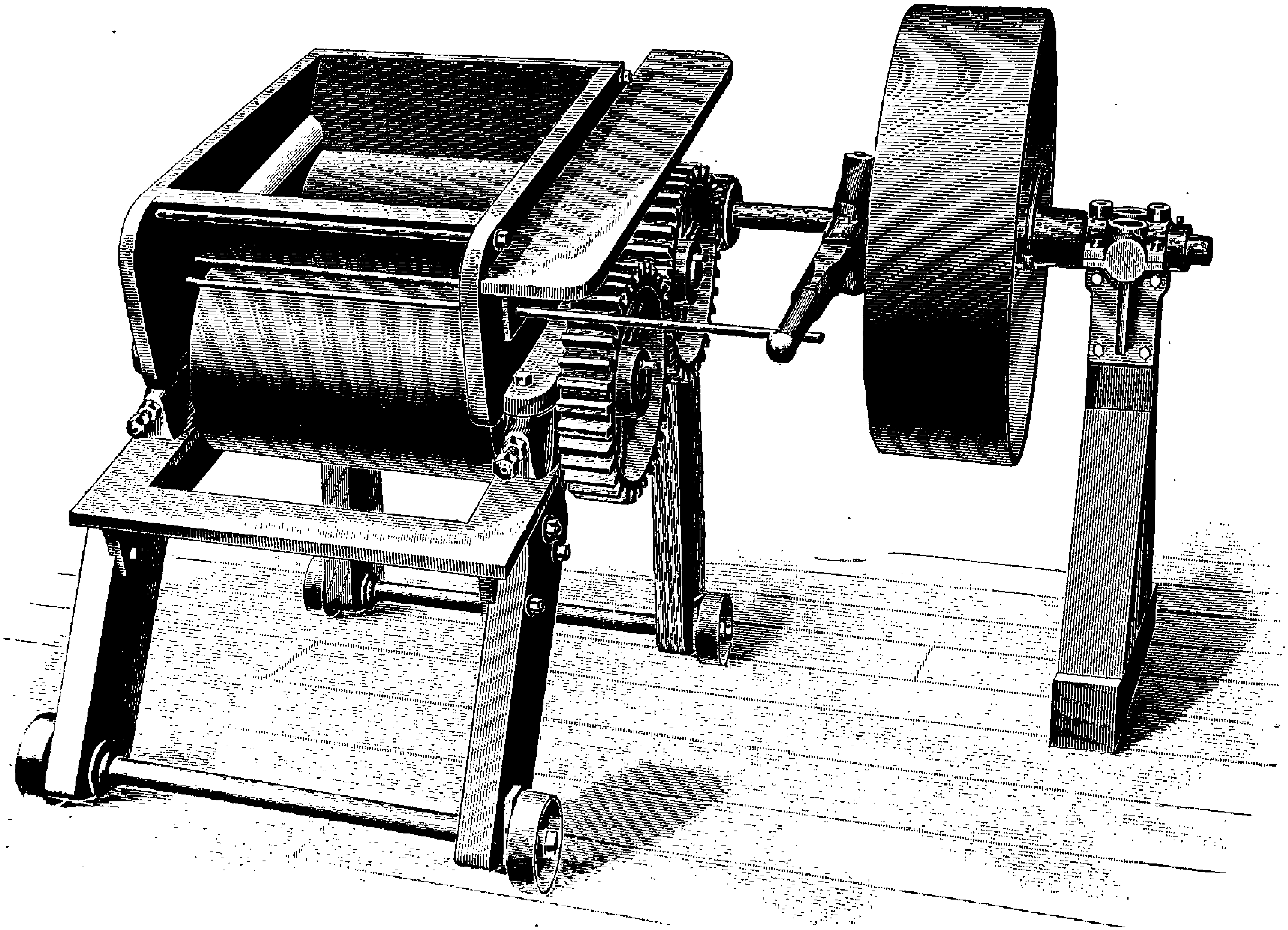
Fig. 21 illustrates the No. 1 Two Roll Crusher built by the Frey-Sheckler Co., which is made for exceedingly stony clays. The frame is cast in one piece and the boxes have heavy rubber springs behind them. The rollers, 16 inches diameter and 24 inches long, are made of charcoal chilled iron with a 3-inch steel shaft through them. The steel scrapers are placed on lugs with slots in them, so that they can be easily adjusted to the face of the roll as the edge wears off. This is a very strong and durable crusher, and is a desirable substitute in places where other crushers failed, owing to weakness in construction. This machine is provided with a patent friction clutch pulley. Diameter of driving pulley, 36 inches; face of driving pulley, 10 inches; speed, 200 revolutions per minute; weight, 2,700 pounds.

Fig. 22 illustrates the Four Roller Crusher built by the Frey-Sheckler Co., and which is made in two sizes, viz.: Nos. 7 and 8. This machine is very heavy, strong and durable, and designed for use in brick factories where large capacity is required.

The rolls are made of the best charcoal chilled iron, mounted on a frame of wrought iron 6 inches wide, 1½ inches thick; each pair of rolls is driven by independent belts. The driven rolls of each pair are provided with sliding journal boxes, which are backed up by heavy steel coil springs. By the use of the sliding boxes, the rolls can be adjusted as may be desired.

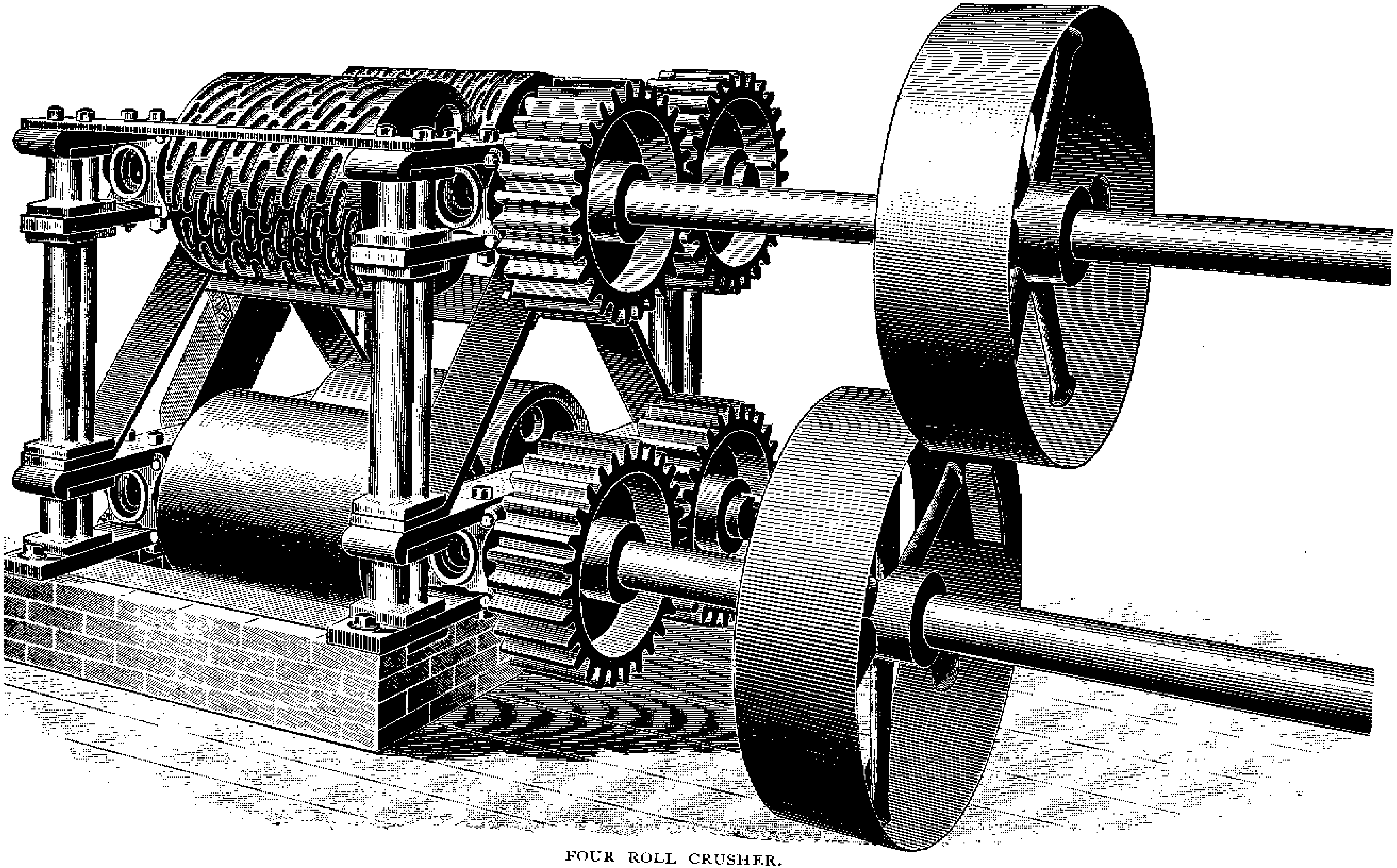
In order to suit the great variety of material to be crushed, the Frey-Sheckler Co. manufacture three styles of rolls to be used for the upper pair. For very lumpy and stony clays,

FIG. 21.



TWO ROLL CRUSHER.

FIG. 22.



FOUR ROLL CRUSHER.

either the patent stone separating or conical rolls are used, and for clays of alluvial nature smooth-face rolls are employed. The rolls are keyed on the shaft and are perfectly balanced. The rolls are supplied with adjustable scrapers made of tool steel, which keep the rolls perfectly clean.

Number 7 Crusher has rolls 16 inches diameter, 24 inches long; driving pulleys 36 inches diameter, 10 inch face. Speed of upper rolls, 250 revolutions per minute; speed of lower rolls, 275 revolutions per minute; weight, 5,800 pounds.

Number 8 Crusher is supplied with rolls 20 inches diameter, 26 inches long; driving pulleys 36 inches diameter, 10 inch face. Speed of upper rolls, 300 revolutions per minute; speed of lower rolls, 325 revolutions per minute; weight, 9,400 pounds.

Both of these Crushers are now supplied with friction clutch pulleys, instead of plain pulleys, as shown in the cut.

PUG-MILLS.

Fig. 23 illustrates the No. 2 Pug-mill built by the Frey-Sheckler Co. This pug-mill has a shell made of ¼-inch boiler steel, 8 feet long. It has cast-iron ends. There are two patterns for ends, at the discharge of mill; in one of them the opening is very large; this is used when the clay is of a very sticky nature, and also where large capacity is desired. The other one has a smaller opening, and is used where the clay is of a short nature, or where a smaller capacity is wanted. The shaft is made of hexagon hammered steel 3¾ inches diameter; the knives are also made of steel, bolted on cast hubs that slip on the shaft. By using a knife of this kind much trouble and expense are saved should the knives have to be replaced. The hubs, fitting on the hexagon shaft, allow the knives to be arranged in any manner desired. Each knife can be set in six different positions, corresponding with the six flat sides of the shaft, and by this arrangement of the knives the clay can be discharged rapidly, or retained in the mill longer, and the tempering controlled in this manner. The knives on shaft outside of the discharge head of mill cut the clay as it

FIG. 23.

NO. 2 PUG-MILL.

emerges through the head, and allow it to fall to the machine or conveyor below. This device makes the flow of clay even to the machine, and cuts the clay in small pieces, so that the machine will take hold of it readily.

The gearing is very heavy, being geared six to one. The builders say: "Our long experience has taught us that wherever dry clay is desired to be mixed with water in the process of passing through the pug-mill, that an open-top pug-mill is the only safe machine to use. The reason for this is that an open-top pug-mill allows the examination of the clays all along the course, and the introduction of additional water to even it up. Closed pug-mills are only advisable where the clay is tempered before entering into them, or where it runs perfectly even in moisture in the bank, and requires no additional water. This mill will pug clay for 30,000 to 60,000 brick in 10 hours, depending on the nature of the clay and the arrangement of the mixing knives." It is provided with a friction clutch pulley 36 inches in diameter, 10 inch face. Average motion, 150 revolutions per minute: weight, 4,200 pounds.

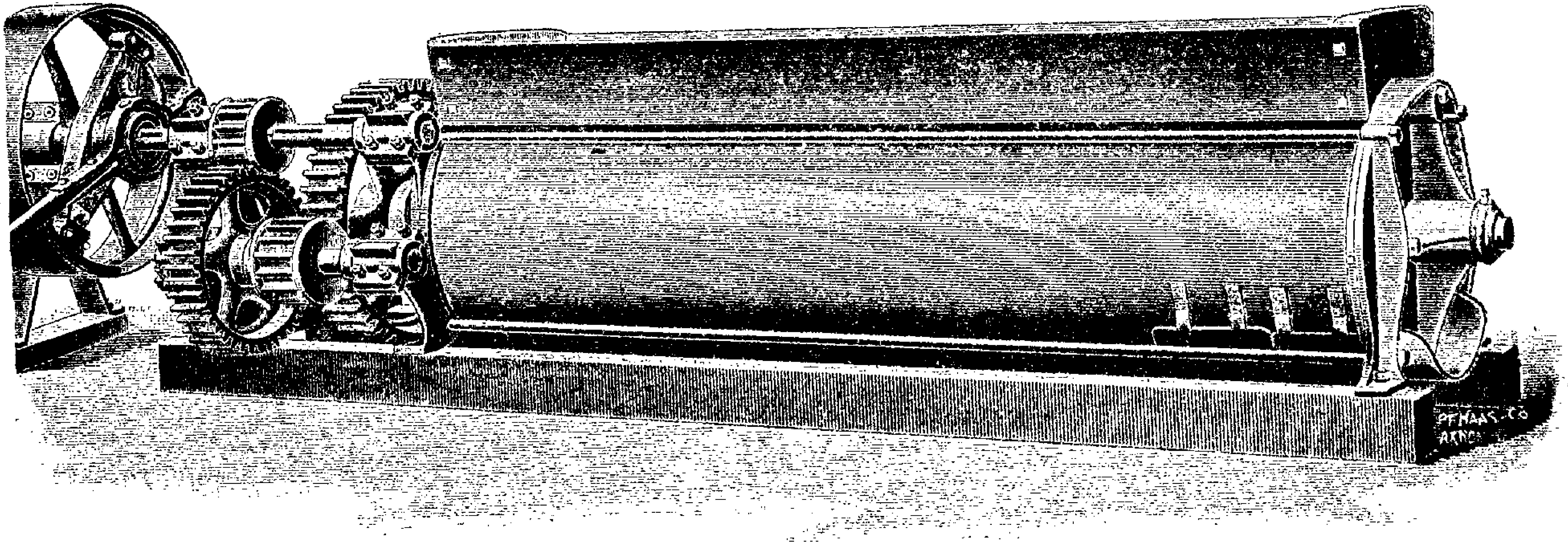
Fig. 24 illustrates a Double Geared Pug-mill made by the Frey-Sheckler Co. in two sizes, viz.: No. 5, 10 feet long: No. 6, 12 feet long.

This pug-mill has a shell made of ¼ inch boiler steel. The heads are made of cast iron, and of the same pattern as is used in their No. 2 pug-mill.

The shaft is made of hexagon hammered steel 3¾ inches in diameter; the knives are made of cast iron and bolted in cast socket hubs that slip on the shaft, the same as in their No. 2 pug-mill. This pug-mill is double geared, made extra heavy and strong. It can be arranged to discharge the clay either from the bottom or at the end.

The capacity of No. 5 pug-mill is for from 30,000 to 50,000 brick in 10 hours; No. 6 pug-mill 50,000 to 75,000 brick in 10 hours, depending upon the nature of the clay and the arrangement of the mixing knives. It is provided with a friction clutch pulley 36 inches in diameter, 10 inch face. Average

FIG. 24.



DOBLE GEARED PUG-MILL.

motion, 160 to 170 revolutions per minute; weight, 5,700 pounds.

MOULDING STIFF-CLAY BRICK.

For the moulding of stiff-clay brick many different machines have been made, and England and Germany stand prominent with the United States in the construction of suitable machinery for this purpose. We have selected such machines of this class as seem to have the most prominent features, together with the latest improvements for the purpose of description.

Before entering upon a detail of this machinery itself, it is necessary to give the reader a full explanation of the requirements which brick made by this class of machines should meet; also reciting the defects which improper constructions of the moulding devices often impart to stiff-mud-made brick. Owing to defects in manufacture, brick often disintegrate in the Northern climates by the action of the weather.

In New York, where the manufacture of brick reaches over one hundred millions per annum, it was noticed that stiff-mud-made brick would not last as well as those made of soft clays, and attention was called to the fact in the National Convention of Brick Manufacturers, by experienced and conscientious brick manufacturers. Fortunately some experts of large experience in the manufacture and operating of brick-making machinery were present at the convention, and as these experts were persons of practical knowledge acquired in Germany, England, Australia, and America, they afterward pointed out by publication wherein the cause of the disintegration of the brick could be found, namely, in the improper construction of the moulding devices.

A gentleman stated that he constructed a machine in Germany, some twenty-five years since, and obtained a contract from a railroad company to furnish the brick for some buildings along the road; the brick being admired for their beauty and seeming density. After two winters had passed, however, these nice-looking brick commenced to shell off and presented a very shabby appearance. This led him to study the philosophy

pertaining to the flow of clay through dies, and how to prevent the lamination of the clay in the brick, which was the only cause of his ill-success in his first attempt in making stiff-mud brick. He found, like all his coadjutors, that the flow of the clay must be equalized as it passes the mouth-piece, and that the pressure back of it must conform to these requirements. The use of lubricating dies of proper construction and change of forcing augers remedied the difficulties, and the brick that he afterwards made of the same clay, with the same machine, are now as good as when they were put into the walls; this statement being verified by an examination made of the brick only a short time ago.

Manufacturers of this class of machinery in America went through the same experience, but were later in discovering the remedy.

It can be readily seen, that when brick are made on a die that does not lubricate the corners properly, the clay will hang back and that the centre will flow faster than the corners. This makes a disruption in the bond of the material, and the brick will be moulded with the clay in layers, or so called laminations.

These laminations are generally in an oval form, when made in auger mills, whereas stiff-mud brick made on plunger machines have straight laminations across the narrower cross-sections of the brick.

The causes of these defects are often found outside of the construction of the moulding part of the machine, being also produced when the clay is worked too dry, or when it has been improperly tempered.

The defective brick which elicited the acknowledgments of the makers before the Convention were made with a machine of excellent construction, but so designed as to force out only one stream of clay for end-cut brick, and at a rapid rate. The opening for the die being in a straight range with the end of the shaft, hence the clay was gathered in from a large area around one central point, which caused the brick to become shelly lengthwise, when the clay was being worked rather stiff

To overcome this objection, the constructors of the Giant, Acme, Centennial and Mascot machines have adopted a die for end-cut brick, with two openings, and use an auger of large dimensions. These orifices are placed far enough apart to avoid this central point of the shaft, and are spaced so that the pressure of the wings of the screw propellers acts alike over the whole surface of the opening. A very compact and solid brick is the result, even from non-lubricating dies.

When the die is made lubricating after the Niedergesæss Patent, very little difference is noticed in the centre stream of a three-stream die, if placed far enough away from the propeller.

In the Acme Brick Machine, the die front is made telescopic, so as to allow for such adjustment.

While end-cut brick do very well for paving purposes, they are not liked so well by bricklayers, owing to the smoothness of the surfaces where the mortar is put on, and also because the ends are not so smooth when cut by the wire or knife, whereas side-cut brick have smooth edges all around, and are just rough enough to hold the mortar well.

Until the Niedergesæss Patent Lubricating Brick Die was introduced, the making of side-cut brick was an uncertain process. Occasionally a quality of clay was found that would work pretty well with a dry die, or the imperfect lubricating dies of the past, yet the defects heretofore named were more or less apparent; while many clays could not even be moulded, owing to the tendency of the clay to stick in the corners, especially when the temper of the clay was uneven.

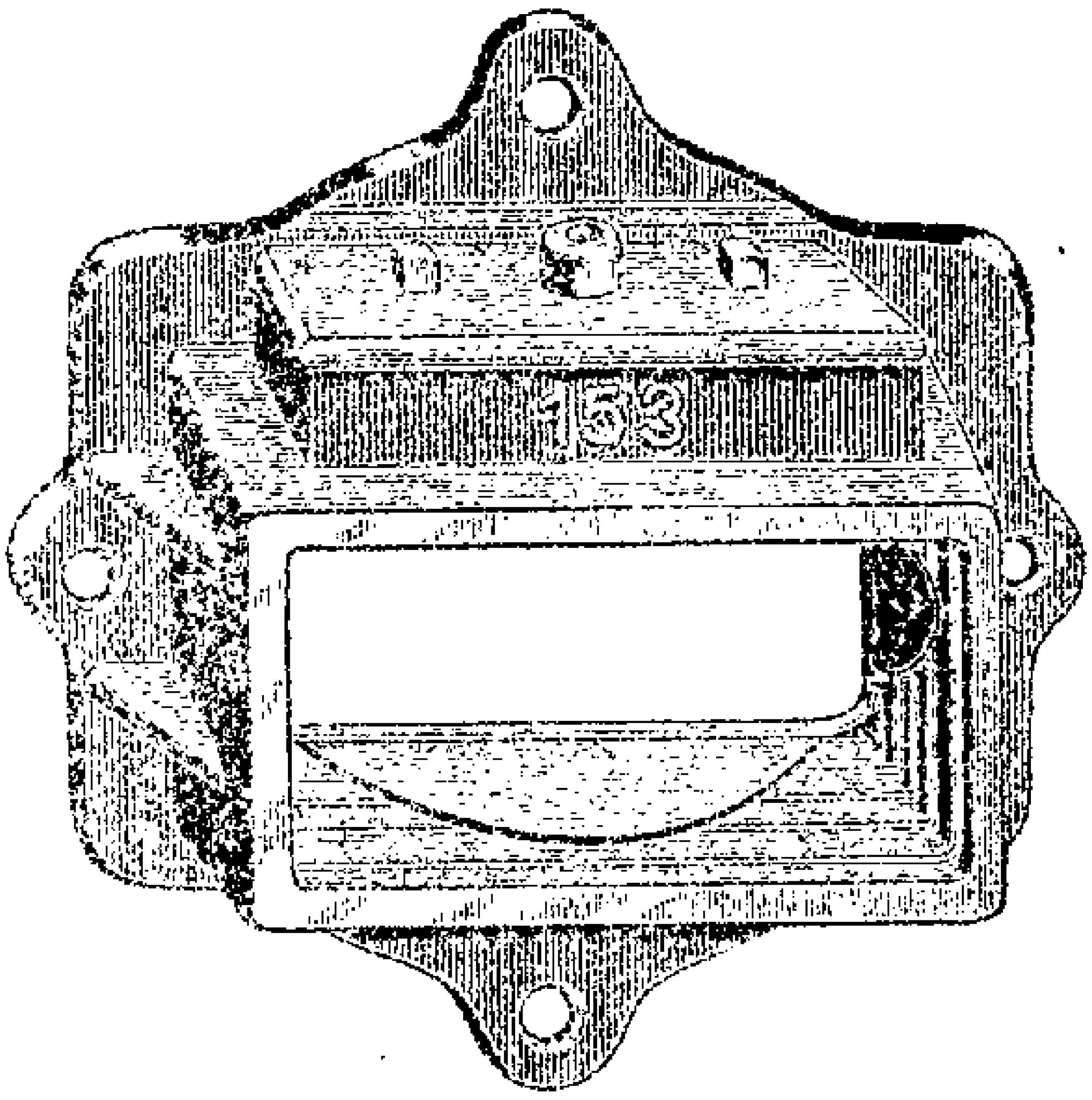
There has heretofore been another serious trouble in having dies retain their proper size so that the brick will be uniform in measurement. In very gritty clay the wear is very rapid, even when the die is made of hard material. This has also been overcome by the die which is illustrated in Fig. 25.

NIEDERGESÆSS PATENT LUBRICATING BRICK DIE.

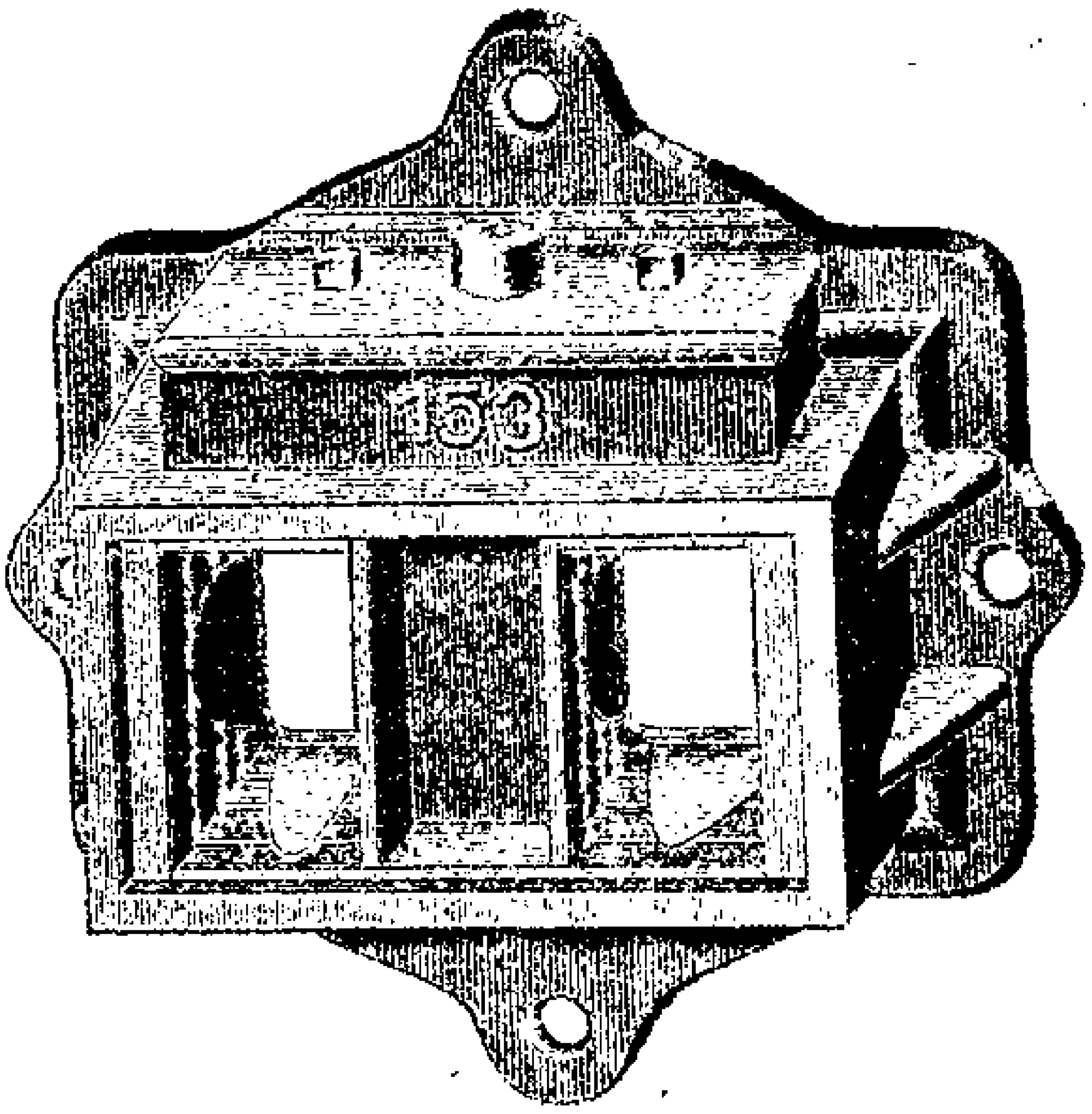
This die consists of a number of parts, as shown in Fig. 25. Number 462 is the casing proper, which contains all the parts

represented as spread out below. This bolts on to the mouth of the machine. On top of this casing two bolts are shown sticking out of the water reservoir, which is provided with channels and holes in the bottom to conduct the lubricating fluid

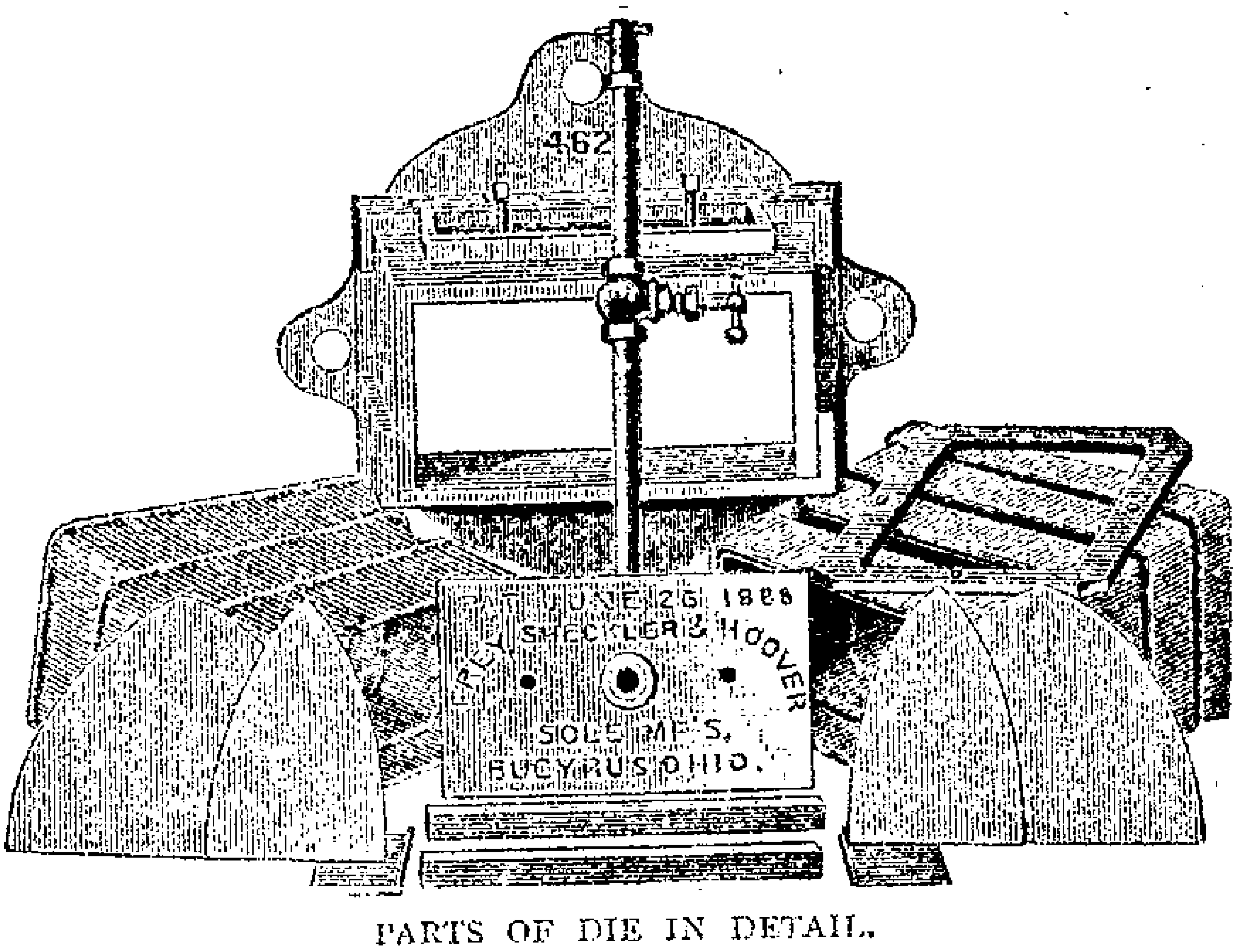
FIG. 25.



SIDE-CUT.



END-CUT.



PARTS OF DIE IN DETAIL.

or steam through the various channels. The bolts fasten the lettered plate, represented in the foreground, on the reservoir. The hole in the centre of the plate is to receive the connecting pipe with valve, also given in cut, which may either lead to the

boiler or a water tank, or if used for re-pressing, to an oil reservoir.

On the right are shown four cast frames having channels around the edges of them. The left shows the sheet steel liners, which fit over each frame. In the immediate front, four sheet steel plates are shown. These fit into the first frame and make the sharp corners on the brick. When round corners are desired, these are replaced by a liner similar to those on the left.

The four round-edged plates in the foreground are termed the aprons, and are put in last over all the liners. The whole is held in by the frame represented on top of the frame on the right. Proper packing, cement or putty, is used to prevent leakage.

The duties of the aprons are two-fold: to prevent the wearing of the liners and to exclude the lubricant where not wanted, so as to insure an even flow. It is highly necessary that only clean fluid be used, as otherwise the channels will stop up and make the die inefficient. It is well to have a thin-bladed knife to put under the liners occasionally, so as to keep them open for the fluid to emerge and come in contact with the clay as it passes through. For some clays dry steam answers the purpose better than either water or oil. Weight, 80 pounds.

With this die a much larger quantity of ware is made, and with less power, than on dies of any other construction.

This system is now applied by the Frey-Sheckler Company to other kinds of dies besides those for brick, such as dies for moulding flooring-tile, grate-backs, flue-tile, and hollow-blocks.

For building-brick sharp corners are demanded, which this die forms very perfectly, while all dry dies must have the corners more or less rounded so as to assist the moulding of them.

THE MASCOT MACHINE, WITH DAISY CUTTING TABLE.

Fig. 26 illustrates the Mascot Machine, with Daisy Cutting Table, built by the Frey-Sheckler Co. This machine is admirably adapted to meet the requirements of persons having light

Fig. 26.

MASCOT MACHINE WITH DAISY CUTTING TABLE.

power and desiring to operate a factory on a small scale. While embracing the essential features of the larger machines, it is smaller and of less capacity.

To run the machine to its full capacity will require about 15 horse-power, depending upon the nature of the clay. The Mascot is adapted to the manufacture of tile from 2 inches to, and including, 10 inches in diameter; brick from 10,000 to 15,000 per day of 10 hours, depending upon the kind and condition of the clay. It is also well adapted for manufacturing hollow building-blocks. Speed, 180 revolutions per minute; friction clutch pulley 36 inches by 10 inches.

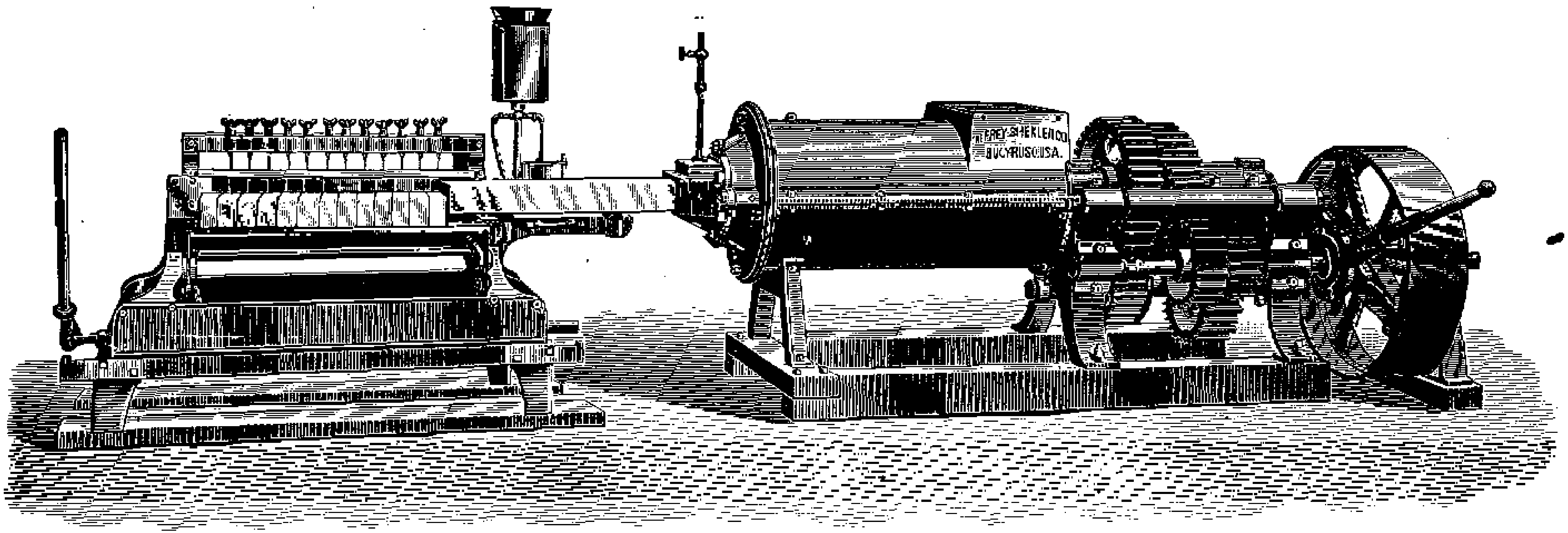
Although the Daisy Cutting Table is quite small, and as only four brick are cut at a time, it is well adapted for cutting from 15,000 to 20,000 brick in 10 hours. One of its many good features is its "down cut," thereby leaving the brick with smooth edges. The abutment plate is hinged. After the cut is made the table is moved back, which releases the abutment plate, allowing it to fall back out of the way in removing the brick, which is done before the cutting-frame is raised. In its construction large wheels are used to reduce resistance. A counter-weight is attached to the cutting-frame, which accelerates the cutting of brick. The Daisy can be used for cutting end and double wedges if desired. It is only intended for side-cut brick. The Mascot Machine and the Daisy Cutting Table combined occupy a floor space 4 feet by 13 feet. Combined weight, 2,650 pounds.

Fig. 27 illustrates the Improved Centennial Brick and Tile Machine, with New Pattern Side-Cut Board Delivery Table, as built by the Frey-Sheckler Co.

One of the many valuable features of this machine is its great pugging capacity. It is provided with two shafts, which revolve in opposite directions, one running at a speed five times faster than the other.

The mixing shaft on which the tempering knives are attached is hollow, and the propeller shaft passes through it with a propeller attached on the outer end; by this arrangement com-

FIG. 27.



IMPROVED CENTENNIAL BRICK AND TILE MACHINE.

plete pugging is assured, also the very best quality of ware produced. The mixing shaft is made of cast steel, and the propeller shaft of forged steel. Its great forte is in making a larger variety of work of superior quality than any other machine.

It is adapted for the production of hollow building-blocks of every description, fire proofing, terra cotta lumber, drain tile, building and fire-brick.

The construction throughout is of the best and simplest.

The gears are new and of heavy pattern, having 5½ inch face, 1¾ inch pitch.

It has a capacity of 15,000 to 20,000 standard size brick per day, depending upon the kind and condition of the clay.

A 36-inch diameter, 10-inch face friction clutch pulley is supplied with this machine, running at a speed of 100 revolutions per minute.

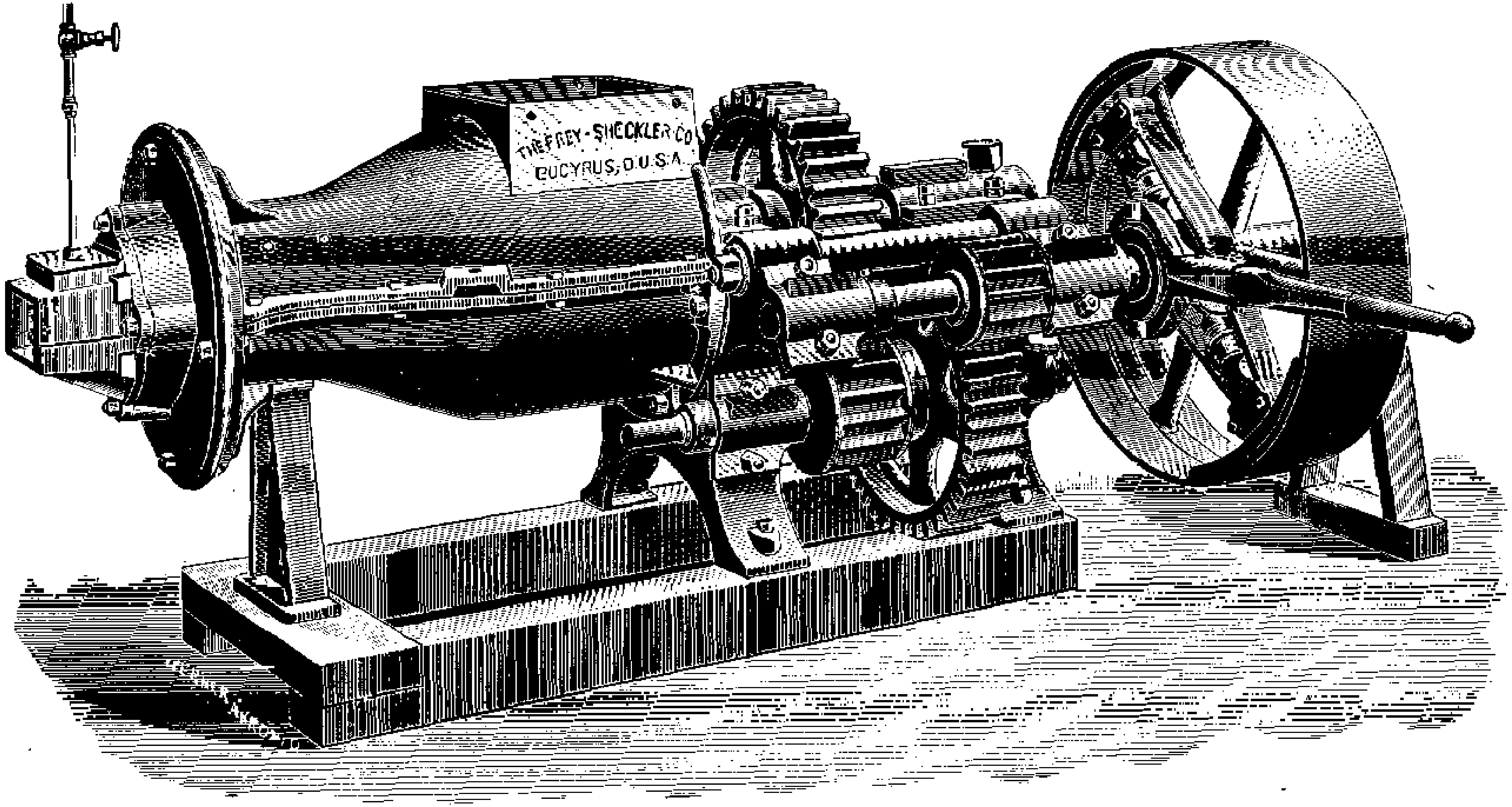
The machine proper will occupy a floor space of 12 feet by 4 ft. 6 inches.

Approximate weight, 4,000 pounds.

Fig. 28 illustrates the Improved Acme Machine, built by the Frey-Sheckler Co.

This machine is so well known among clay-workers that little need be said as to its merits. The Acme has been on the market many years, and for excellence of performance, size considered, it is to-day without an equal. It will be observed from the accompanying cut that the construction of the main frame is very rigid. The gearing is remarkably strong. The auger shaft is made of forged steel, provided with two bearings ten inches and twelve inches long respectively. The auger and knives are made of charcoal chilled iron, rendering them exceedingly durable. All parts are accessible. The machine is so constructed that the augers and knives can be readily examined and replaced when necessary. There are no parts liable to derangement. Like all their machines, the acme is provided with a friction clutch pulley 36 inches diameter, 10 inch face, which places it under the immediate control of the operator. It is adapted to the manufacture of brick, tile and hollow

FIG. 28.



IMPROVED ACME MACHINE.

blocks, making tile as large as 20 inches in diameter. On brick its capacity is rated from 20,000 to 30,000 standard size brick in ten hours. Speed 200 to 225 revolutions per minute. Approximate weight 4,000 pounds. Occupies a floor space 9 ft. 6 in. by 5 ft.

Any of the cutting tables made by the Frey-Sheckler Co., can be used in connection with the Acme machine.

Fig. 29 illustrates the Special Bucyrus Giant Machine, as manufactured by the Frey-Sheckler Co.

The mixing shaft is made of hammered steel, 5½ inches in diameter, hexagon, where the knives are fitted on, and 6½ inches in diameter where the large spur wheel is fitted on.

The intermediate shaft is made of hammered steel, 4½ inches in diameter where the intermediate gear and pinion are fitted on, and 4 inches in diameter at the bearings.

The driving shaft is made of hammered steel 3½ inches in diameter.

The gearing is of the latest design, extra heavy and strong.

The main spur wheel and spur pinion are 10 inches face, and 12 inches over housings, 2½ inches pitch.

The intermediate gear and driving pinion are 8½ inches face, and 10¼ inches over housings, 2½ inches pitch.

Both the intermediate and driving pinions are made of cast steel.

By having the gearing housed there is secured from 25 to 35 per cent. more strength on the same size gear than on the ordinary plain gearing. The manufacturers therefore give a surplus strength.

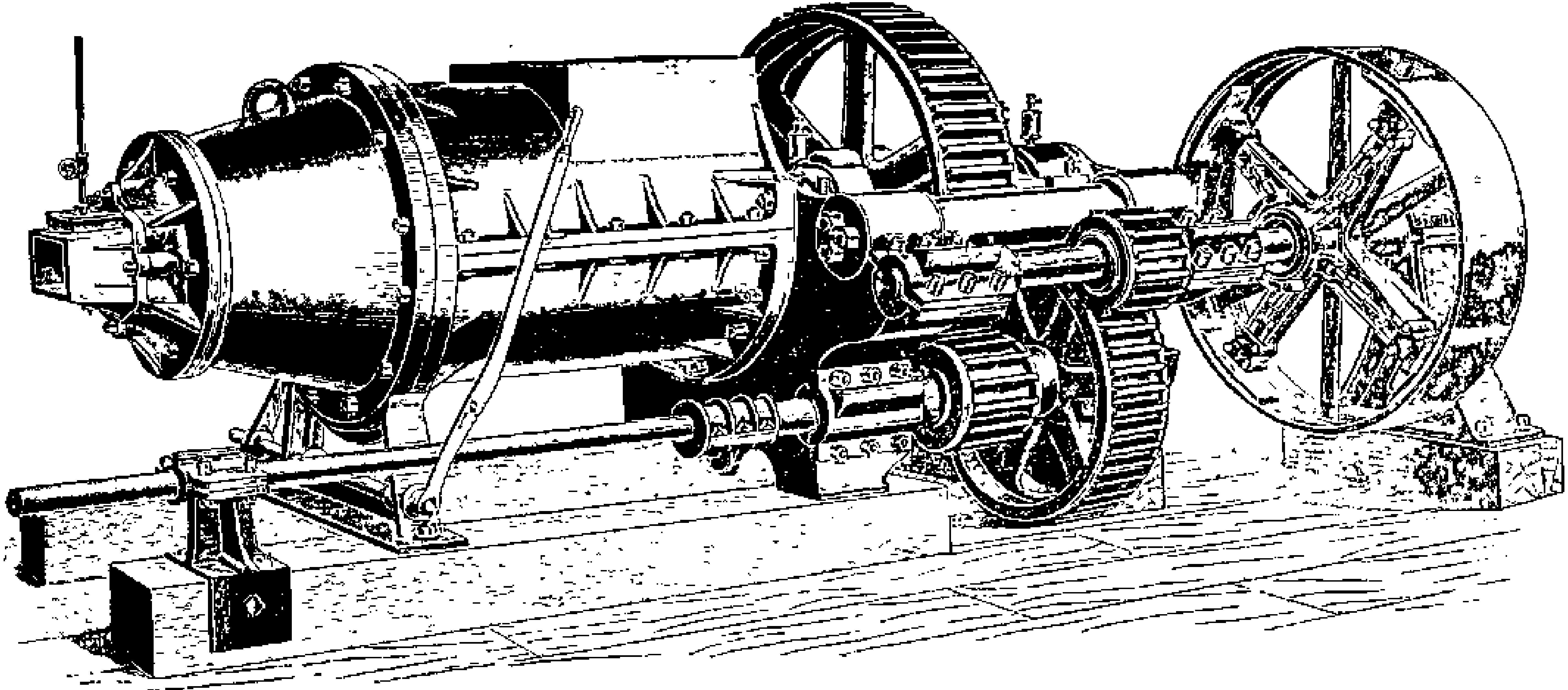
The machine is back-geared 12 to 1, which renders a very strong and easy motion.

The driving pulley is of the friction clutch pattern, 48 inches in diameter, 12 inches face. Speed, 300 revolutions per minute.

The concaves are securely fastened to the front gear frame; the side and end flanges are planed and bolted to each other; the flanges are ribbed to the body. The opening in the top concave is 24 inches by 24 inches.

The nozzle is planed on both ends, and securely fastened to the concaves.

Fig. 29.



SPECIAL BUCYRUS GIANT MACHINE.

The front which receives the dies is also planed on both ends, so as to make a perfect joint; it is secured to the nozzle with extra heavy cast-iron hinges, thus enabling the operator to clean the machine or remove the die readily.

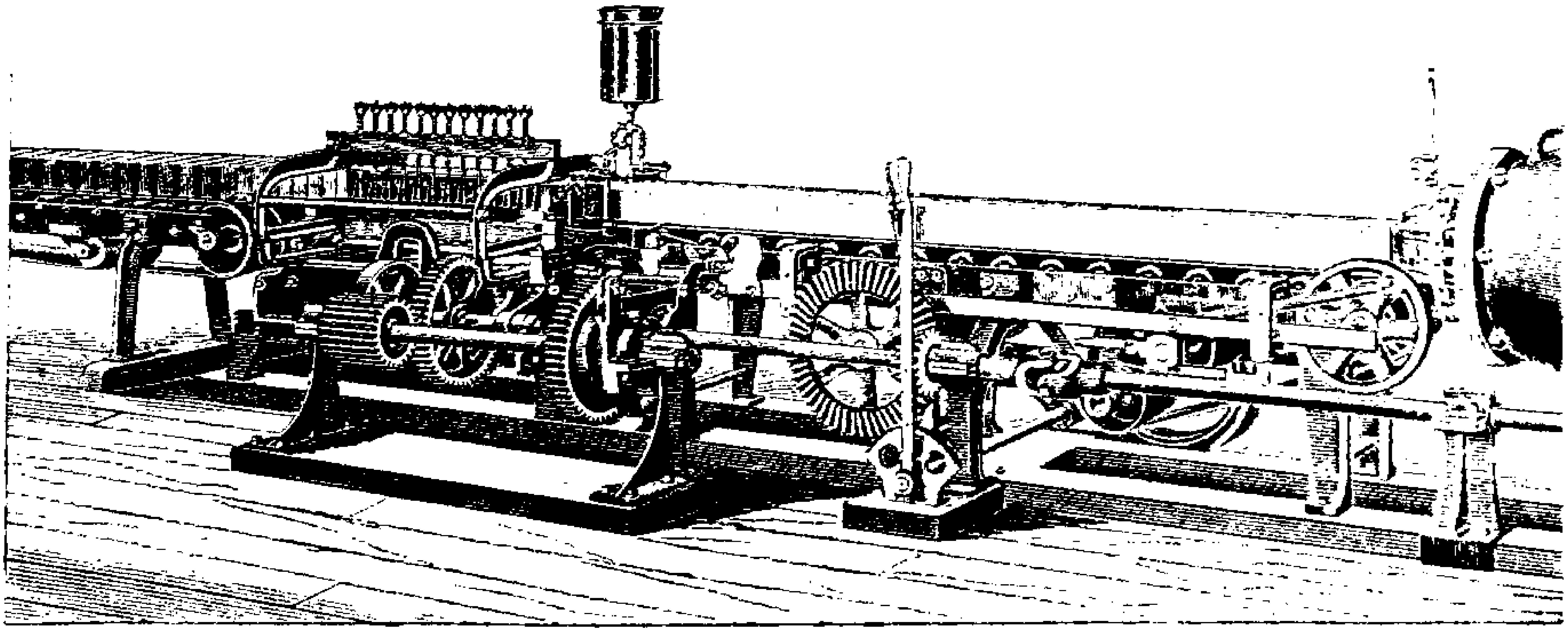
The front end of the machine is supported with an extra long leg, which is bored out to fit the turned end of the concave and nozzle.

The gear frames are made extra heavy, so as to give surplus strength. They are planed and fitted together nicely. Both bearings of the main shaft in the gear frames are 18 inches long and 5½ inches in diameter. The bearings of the intermediate shaft are 14 inches long, 4 inches in diameter. The bearings of the driving shaft are 14 inches long, 3½ inches in diameter.

Capacity, 50,000 to 80,000 standard size brick per day of 10 hours, depending upon the quality of the clay, temper and treatment. Approximate weight, 20,000 lbs.

In addition to the Special Bucyrus Giant Machine, the Frey-Sheckler Co. also mannfacture the No. 1 and No. 2 Giant Machines.

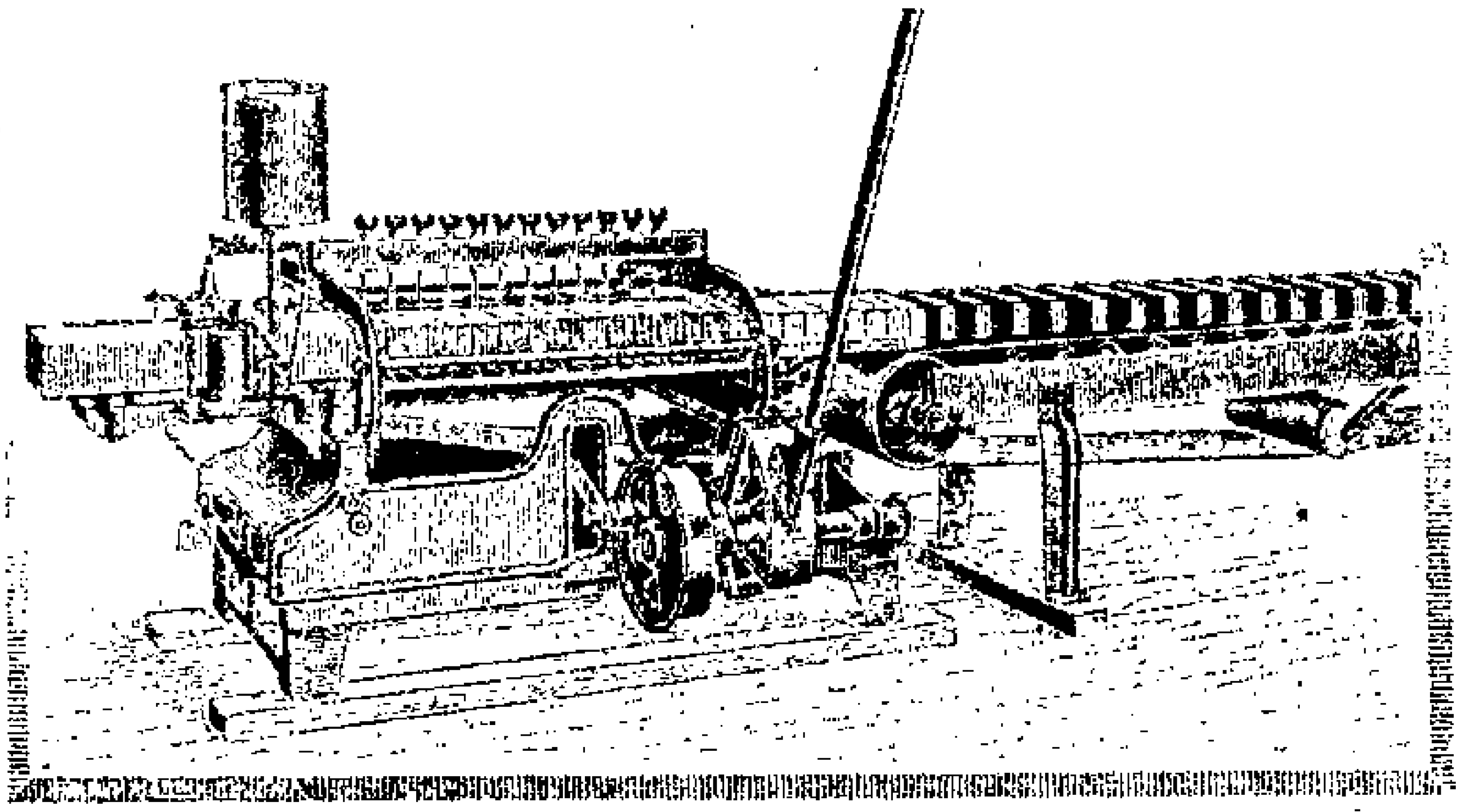
FIG. 30.



BUCYRUS SIDE CUT AUTOMATIC TABLE.

Fig. 30 illustrates the Bucyrus Side Cut Automatic Table as built by the Frey-Sheckler Co. It has a capacity of 40,000 to 100,000 brick every ten hours.

FIG. 31.



WELLSVILLE SIDE CUT TABLE.

Fig. 31 illustrates the Wellsville Side Cut Table as manufactured by the Frey-Sheckler Co. It cuts any number of brick desired from 20,000 to 70,000 brick per day.

DRYING THE BRICK.

The different methods of drying brick may be classed as follows: First, when brick are spread out on the ground to be dried by sunshine. Second, the shed system, where stiff-mud brick are hacked under sheds and dried by natural air-currents; soft-mud bricks are dried on the same principle by the use of racks and pallets. Third, by artificial heat—the first and oldest method of employing artificial heat for desiccating brick being to dry them by laying or hacking them on a hot floor. This is known as a hot floor or flue dryer. This floor is heated by a system of flues passing under it, from furnaces at one end to stack at the other end. The second method by the use of artificial heat is the tunnel system, where brick are put on cars, either hacked on the bottom of car or resting on hacking pallets. The cars are passed through heated tunnels, and when dry are carried direct to the kiln on the cars. Of this class there are several kinds. Another plan is to place them in cupboards, and drive hot air through them by means of blowers which supply heat to the cupboards through hot-air pipes.

The disadvantages of drying brick in the sun are that they are exposed to rain and frost, and the percentage of brick dam-

aged and lost will average 15 per cent. Again, there is no certainty about the supply of sunshine; while it is furnished without price, it is also furnished without regularity, and sometimes, for two weeks at a time, no brick are dried; hence, the brick-maker who depends on this process of drying has an uncertain output indeed. Still there is much more certainty about the output than there is about the number he may put into the kiln. There are only six months in the year during which they can be dried in this way, and only a part of this time is available. Where brick are made in great quantities, a large area for drying the brick is needed, as it must contain nearly a week's production. This necessitates the moving of the brick long distances from machine to yard and from yard to kilns, and also the handling of large quantities of lumber to protect the brick, which requires a good deal of labor, and destroys in a season many thousand feet of the very best lumber. The advantages of sheds over the sunshine process, are there is no loss by storm, and no lumber to handle.

The pallet system is advantageous with soft-mud brick, for they can be dumped from the moulds at the machine. This prevents sticking in the moulds, and when placed on pallets they can be put in racks one tier above another, and a large quantity can be stored in a comparatively small space, and when the racks are provided with projecting roofs or canvas sides, they save the brick from damage by rain, so that shed-drying and the rack and pallet system are great improvements over the old methods, but are open otherwise to the same objections that the sunshine method is, that brick cannot be dried in damp weather.

The general advantages of artificial drying over natural are many, without reference to the advantages of one mode of artificial drying over another mode of artificial drying. With an artificial dryer and a machine capable of producing 25,000 brick per day, a brick-maker can make six millions to seven millions per year. To dry without artificial heat it would require two machines of 25,000 capacity to produce the same

number of brick in a year. Now, with one-half the labor, tools, power, and consequently little more than half the capital, he produces the same results. He then gives his employés steady work, and in this way obtains and retains a better class of men for perhaps less wages. There is much less worry and responsibility; he has no anxiety about a storm coming in the night and damaging or destroying his day's products, or perhaps a week's labor may be swept away, and his yard left in such a condition that he can make no more brick for several days. With proper drying facilities the manufacturer can contract to sell his brick for future delivery, knowing he can fill his orders without being compelled to carry a large stock; instead of having to make his brick in the autumn for the spring market, he can sell his entire product up to the end of the year, and begin in January or February and have brick ready for the early spring market.

In partially drying machine-made brick for repressing, soft-mud brick are usually carried from the brick-machine to the yard or drying-shed, where they remain until they are in condition for re-pressing.

Just here many have their greatest difficulty, as the brick will dry more rapidly on the surface than inside, especially the angles and corners, and by the time the centre of the brick is stiff enough to stand handling, the surface is too hard to re-press. What is needed at this point is to equalize the moisture that remains throughout the brick by taking the brick and setting them in close hacks; then cover them with canvas or old carpets that have been moistened, let them remain a few hours, when uncovered they are ready to re-press. Part of the moisture in the centre has come to the surface, and every part is ready for pressure and handling.

After being re-pressed the soft-mud made brick are often finally dried on a hot floor by setting them on end, and in this way it is possible to finally dry them in three days. To set them on end without injury they must be pressed quite stiff—the safer way is to place them on edge or on their flat side to

dry. Where the hot floor is not used, the brick are often placed on smooth pallets to dry.

Semi-plastic-clay brick may be pressed direct from the machine, as they are then sufficiently dry to be handled from the re-press without injury.

IMPROVED BRICK-DRYING SHED.

The improved brick-drying shed, shown in Figs. 32 to 44, can be used for drying either wet machine-made or hand-made brick.

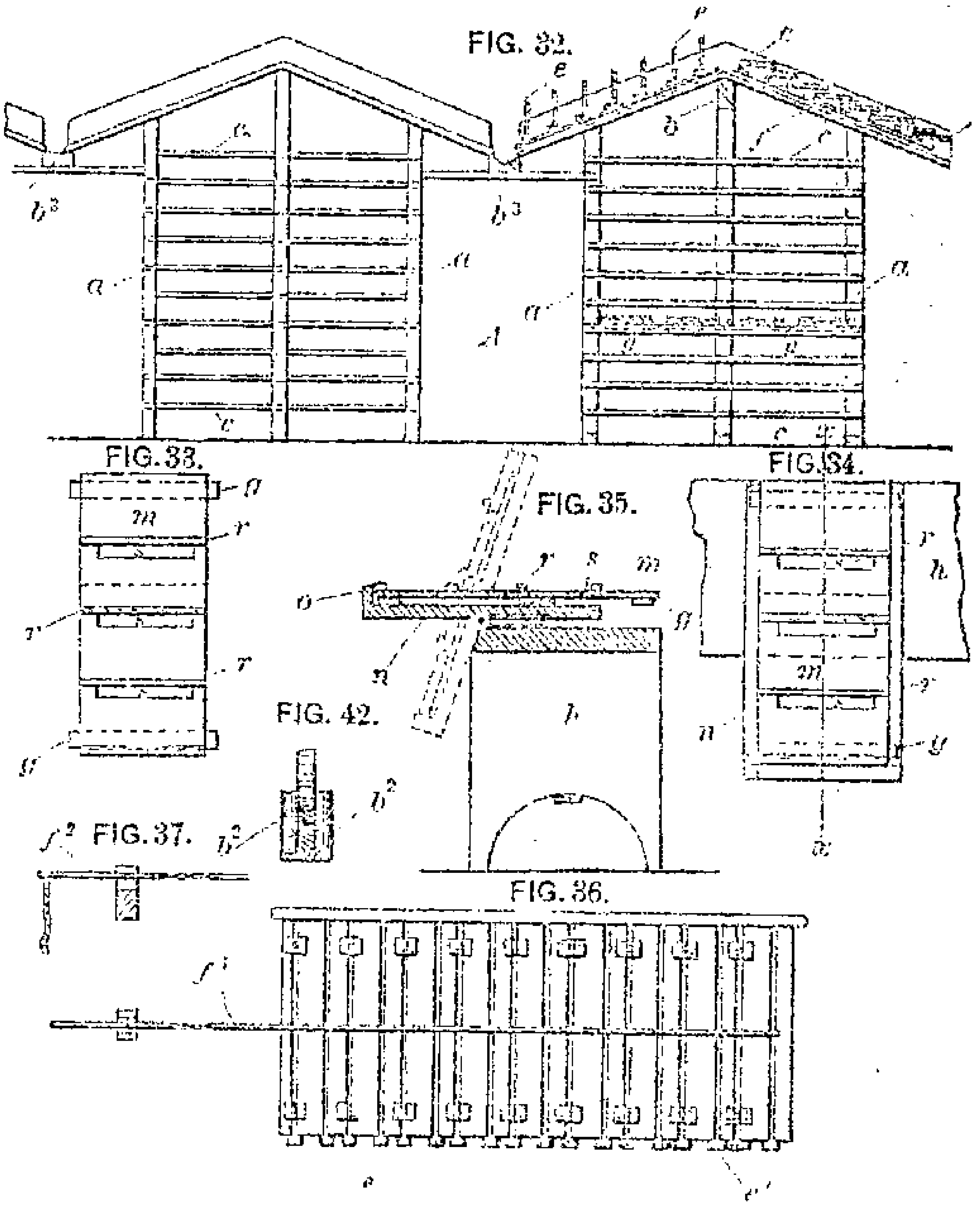
Fig. 32 is an end elevation partly in section. Fig. 33 is a plan of a brick-board. Fig. 34 is a plan view of a part of a bench having attached thereto a mould-lander, or tilting-board, upon which is a brick-board. Fig. 35 is a vertical section taken through line *x* of Fig. 34. Fig. 36 is a plan view of the hinged boards. Fig. 37 is a vertical section of the lifting mechanism attached to the lever of Fig. 36. Fig. 38 is a side elevation of a part of the brick-drying structure partly in section. Fig. 39 is a plan of a brick-board mounted on wheels. Fig. 40 is a side elevation of Fig. 39. Fig. 41 is a cross-section of the ways on which the brick-board car moves, and Fig. 42 is a cross-section of the rafter or beam b^2 in Fig. 38. Fig. 43 is a plan of a modification of the movable roof. Fig. 44 is a vertical longitudinal section taken through a line directly under the rod u' in Fig. 43.

In Figs. 32 and 38 *a a* are uprights, which stand preferably apart at the same distance from one another, being about equal to the length of the brick-boards, as shown in Fig. 38. The uprights support the rafters *b* and receive the cleats *c*, arranged one over the other, and in such a position as that when the brick-boards are laid from one series of cleats to the opposite one the brick-boards will lie approximately level.

The roof may be formed so that it may be opened to allow the sun and air to enter, or be closed to exclude the rain or dew. This may be accomplished by pivoting the roof-boards *e*, Figs. 32 and 38, and connecting them by a strip, *f*, of wood

or iron whereby all the pivoted boards may be opened or closed at once, directly by the hand or by a lever, as shown in Fig. 32.

The brick-boards *m* are formed with projecting cleats *g*, Fig. 33, on the under side, so that when the boards are placed side by side on the cleats in the brick-drying structure the extremities of the brick-board cleats *g* will abut, and thus form an open-



ing between the boards, through which the air may freely pass. The cleats *g* on the brick-boards are arranged to engage with the cleats *c* in the brick-drying structure, so that the boards may be readily and securely held in position without any danger of sliding off. The manner of placing the green brick upon the brick-board is as follows: The tilting-board *n* being in its loading position, as indicated by the dotted lines on Fig. 35, the brick-board is placed thereon, and is held in place by a

stop-piece *o*, and the workman takes the mould from the machine, and, resting it upon the strip *r* upon the brick-board, turns it and deposits the mould, with its contents of green brick, upon the brick-board without injury. This is repeated until the brick-board is full, and when the last mould of brick is laid on, the weight of the brick causes the tilting-board to revolve, which then comes to a horizontal position, as in Fig.

FIG. 38.

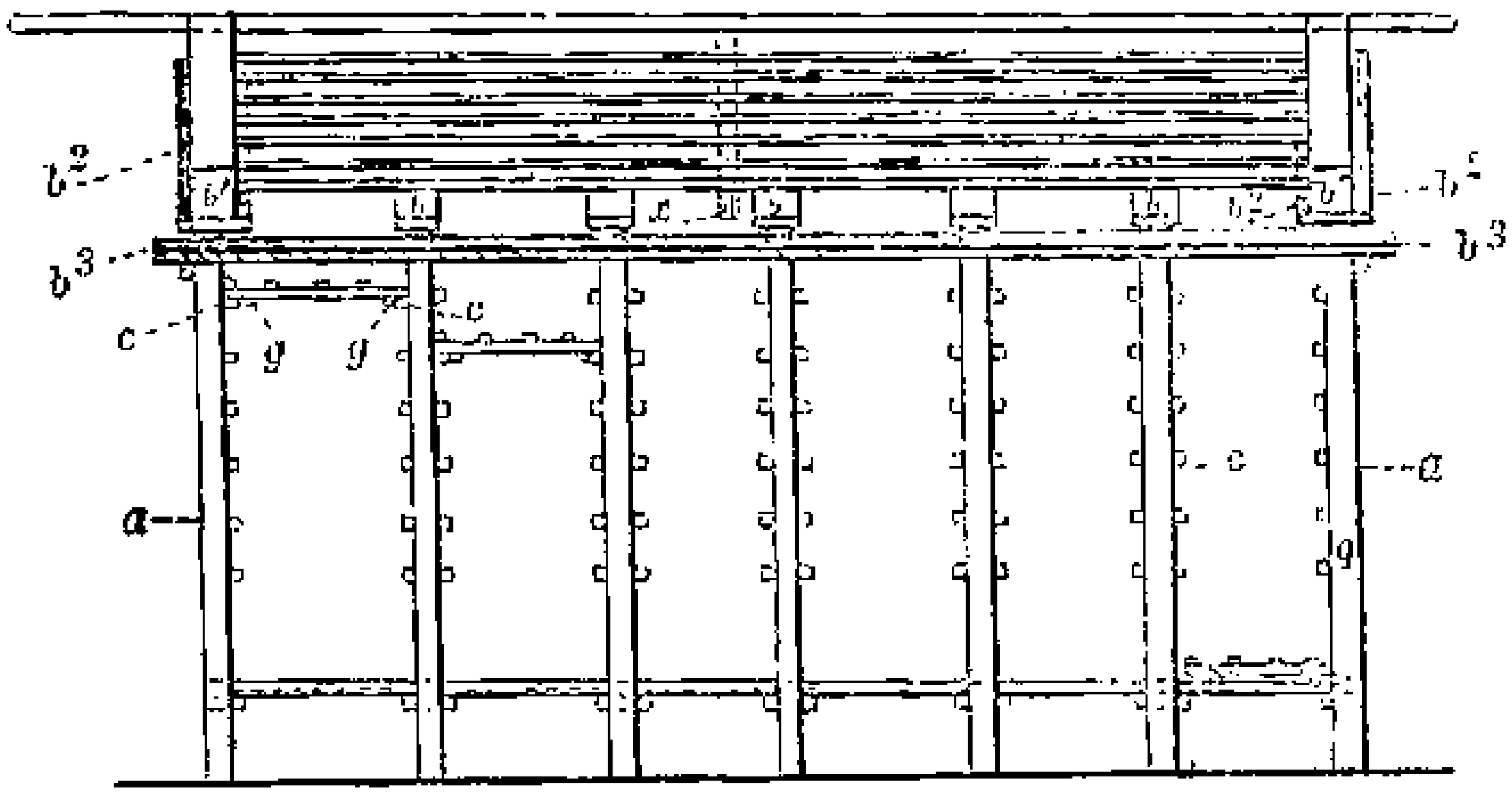


FIG. 39.

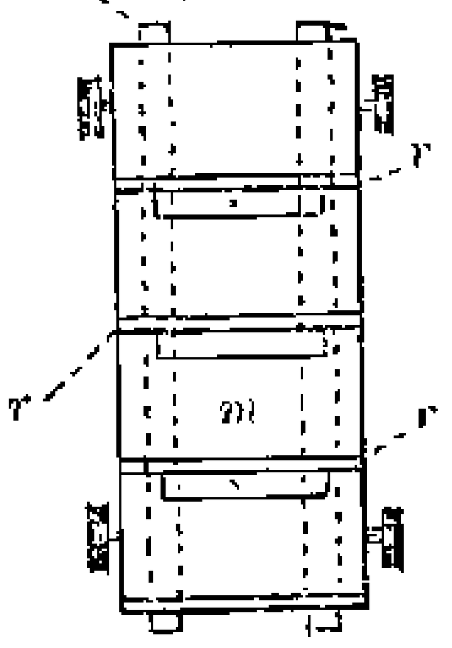
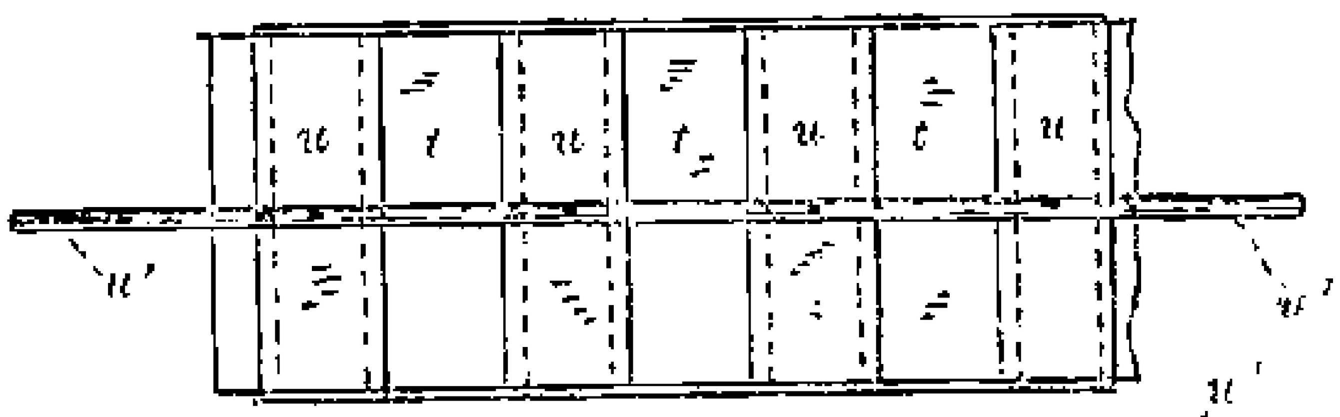


FIG. 40.

FIG. 41.

FIG. 43.



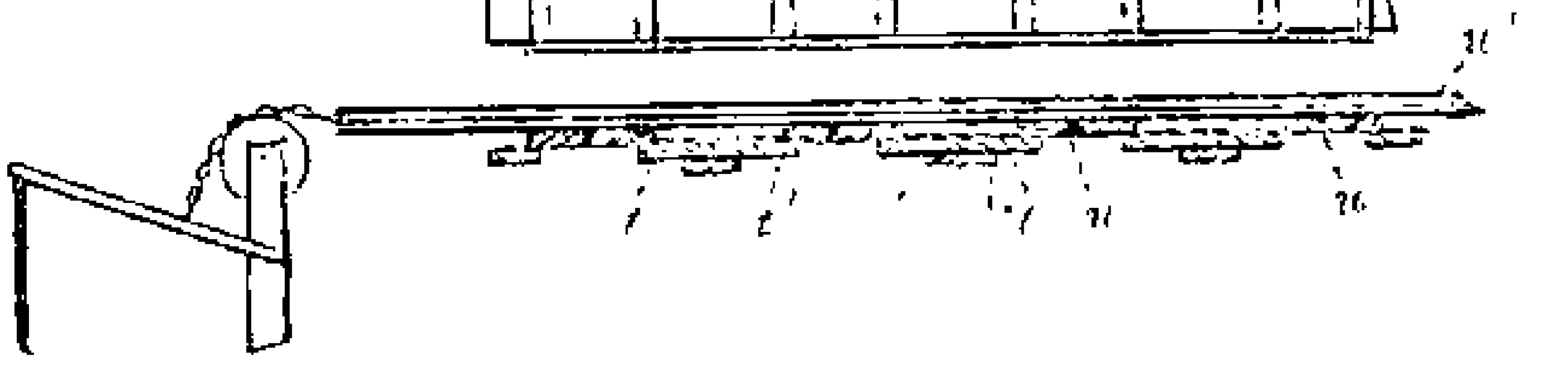


FIG. 44.

35. The moulds being taken off of the bricks, the brick-board, with its load of brick, is then removed to the drying structure, which is near at hand, where they remain without further handling until dry and ready for burning.

The tilting-board *n* is so constructed or pivoted that when the brick-board is removed it returns to its loading position.

Several of these tilting-boards may be placed between the brick-machine and drying-racks—as many as may be necessary.

If desirable, the brick-boards may be mounted upon wheels, as shown in Figs. 39 and 40, either grooved or flat, and move on tracks laid upon the cleats, as in Fig. 38. The cars, after being loaded with the green brick, are placed upon the tracks and moved to the other end, one after the other, until each track is full, and in order to prevent the cars from striking each other too heavily, and thus displace the brick, their descent may be checked, either by a workman or by other suitable means. When the brick-boards are mounted upon wheels, the cleats g^1 on the under side of the brick-boards are placed so that they extend beyond the ends of the cars, as shown in Fig. 39, and thus admit the circulation of air.

The rails may be constructed as shown in Fig. 41. The rail *j* is secured to a strip *k*, and has a side-piece *l*, as a further prevention of the cars slipping off the track.

In order that no moisture can possibly leak through upon the brick, the inventor provides, in addition to the other means, gutters, as b^2, Fig. 38, extending from the ridge-piece to the eaves, under the joints where the shutters meet the rafters b^1, to carry off the water.

The brick-drying structures may be one hundred feet long, more or less, and in building them the inventor prefers to place them so that the eaves of one may touch, or nearly so, those of the other, as shown in Fig. 32, and at or under the point of meeting to provide a gutter b^3, Figs. 32 and 38, suitably pitched and supported, into which the gutters b^2, Fig. 38, and c^1, Fig. 36, may lead. By this construction a covered way *a*, Fig. 32, is made for the passage of the workman, and all the operations can be carried on without regard to the weather, and complete protection is assured.

DRYING BY THE PALLET SYSTEM.

In drying brick by the pallet system various methods are employed. An economical and satisfactory system of drying

by this method consists in delivering the brick after being hand-moulded directly from the mould on to a pallet made of plastering lath 32x11 inches in size, each pallet holding six brick. The pallets are made of pine lath, by placing close together two layers of lath which are separated with five short lath—one at each end and three dividing the distance between, and the two layers of lath and cross lath nailed through at each crossing of the short lath, which makes what we might call a lath pad, that is light and convenient and can be stored in a small space.

The drying cribs are constructed by setting 2″x4″ or 4″x4″ studding in the ground in three rows 27 inches apart in the cross section of the crib, and in the length a sufficient distance to receive the brick pallets on cleats nailed to the cross section of the posts. The two outside rows of posts rise seven feet above ground, and the centre row eight and a half feet. Upon the tops of the posts a permanent roof is constructed.

A cross section, in width of the crib, will hold five pallets of brick (each holding six brick). The cleats on the post begin six inches from the ground, and are set apart so as to receive eleven tiers of pallets, the end of each pallet resting on the cleats, which gives a holding capacity of 110 brick for each foot of the cribs' length. 12 cribs, 130 feet in length, give a drying capacity for over 170,000 brick.

The advantages of this system of drying are the economy of ground space, the avoidance of moisture rising from the earth, the drying in the shade, the protection against damage from rains, the brick are separated so far apart as to dry on all sides alike, and when dry may remain in the crib until removed to the kiln or store-shed, and being handled on the pallets to the kiln they are not marred by breakage or finger marks.

A crib of the size indicated would give a drying capacity for about 30,000 brick made per day.

Store-sheds in which to accumulate a stock of dry brick to burn after the season for moulding closes are necessary where this system of drying is employed.

DRYING BRICK WITH EXHAUST STEAM FROM THE ENGINE.

In whatever system of steam drying is employed, it is essential that the pipes should be of ample size, and that the bends and turns in the pipes be as few as possible, in order to obviate as much as can be done the resistance to the steam, and avoid back pressure upon the engine.

A right-angled turn has the same effect in reducing the velocity as increasing its length about forty times its diameter would have, and consequently these should be avoided when possible.

The entire economy of drying with exhaust steam is neutralized if the back pressure reaches even as low as four pounds, as the extra fuel required to run the engine will, with loss of power and all things considered, be more costly than to employ some separate system of drying.

Of course, with whatever system of steam drying is used, it will be necessary to make ample provision for the use of live steam with which to heat the drier at times when the engine is not in use.

By collecting the water condensed in the pipes in a closed tank and pumping it while hot back into the boiler, saving in fuel should offset any loss from reasonable back pressure. From a paper by Prof. R. C. Carpenter* we glean the following points of practical information in relation to the construction of steam work for driers: the first is the effect of air-traps, the second is the effect of the condensed water, the third is the expansion due to the heating of the pipes.

It is found in steam work that if we have a convex bend in a pipe, as in Fig. 45, air will gather in the upper portion and no amount of pressure will drive it out.

Sometimes it is necessary to have such bends, and in that case a small air-valve will be essential, which can be opened and the air be allowed to escape.

* Read before the Michigan Brick, Tile and Drainage Association, held at Lansing, March 20th and 21st, 1888.

If the bend is the reverse of this, as shown in Fig. 46, condensed water will gather in the low portion; this may in time be blown out or evaporated by the steam, but its action will be to condense the steam and cause pounding and hammering in the pipes. If such a construction is necessary, a drip-valve must be put in such a place and opened from time to time to allow the water to escape.

To avoid both of these evils as much as possible the pipes should ascend to the highest point at once, or in one continuous run from the engine. A vessel with a water-gauge and a discharge-valve should be placed so that this water can drain into it, and as soon as it is full, the engineer can empty it. As soon as the room to be heated is reached the radiating surface is increased to the desired amount, as will be explained later on, and the pipes are then made to descend at least one inch in 12 feet. If the engine is higher than the dry kiln, so that the pipes can descend continuously, it will be much better. The best results in steam heating are always obtained when the condensed water flows with the steam.

FIG. 45.

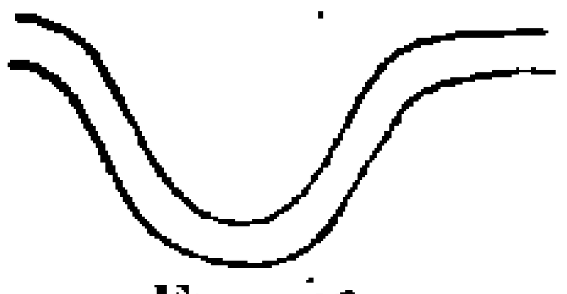


FIG. 46.

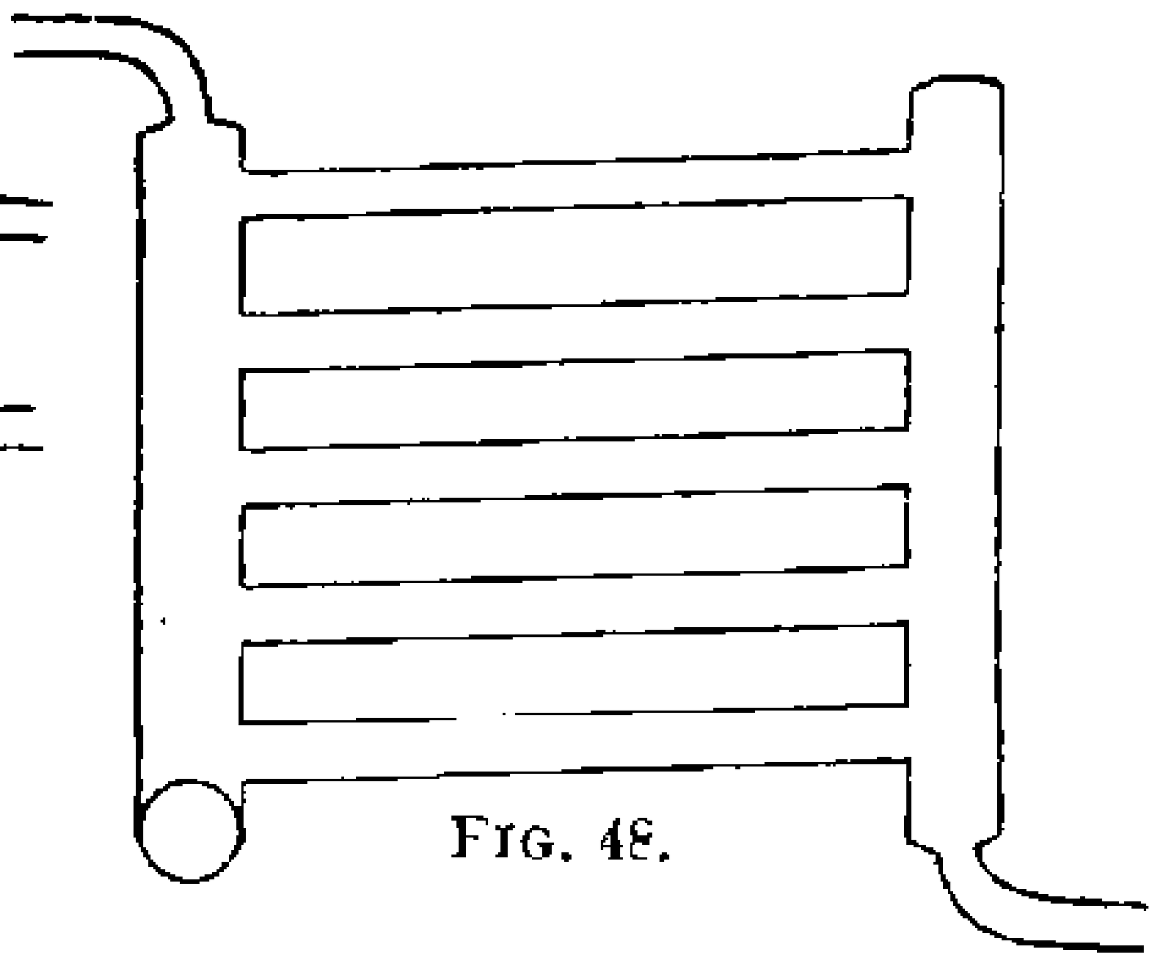


FIG. 48.

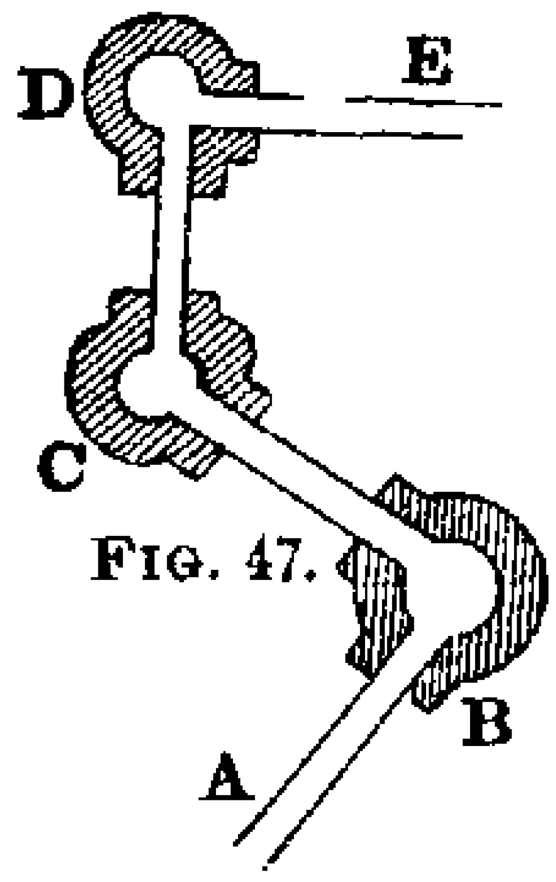


FIG. 47.

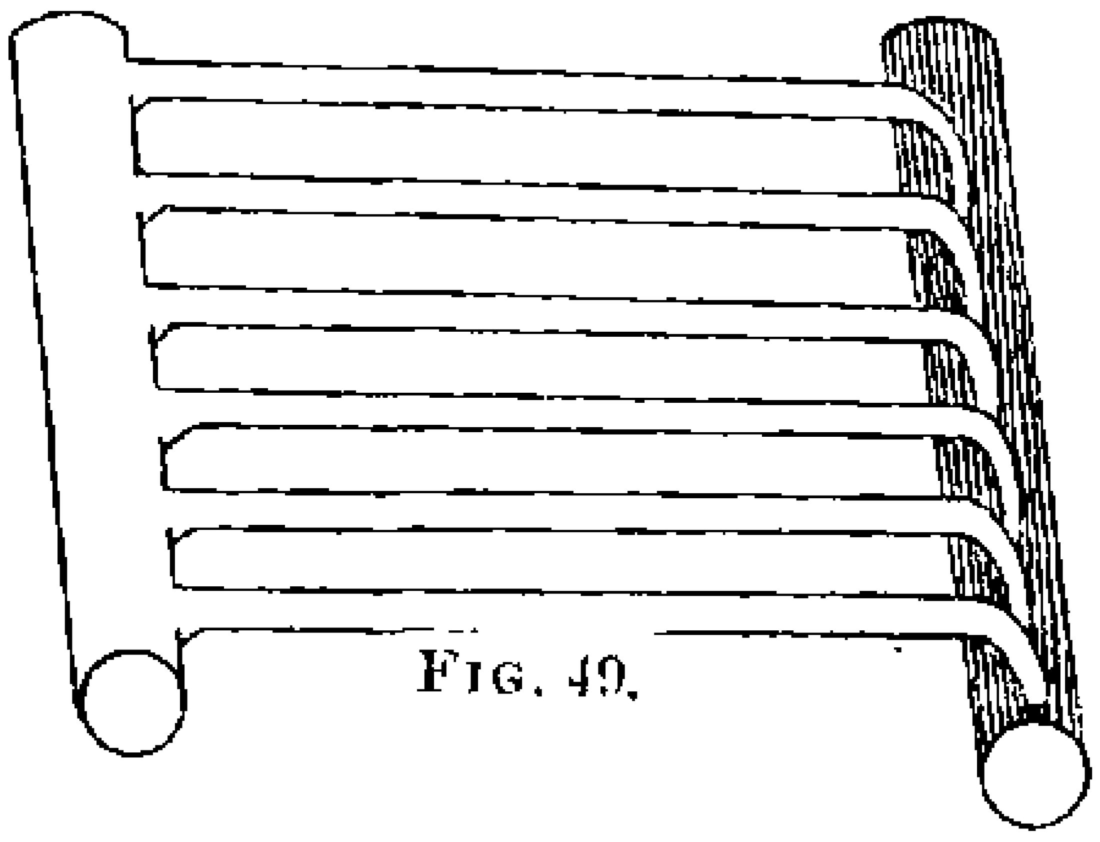


FIG. 49.

To avoid the ill effects of expansion when the pipes cannot be allowed to expand or contract freely we can use especial expansion joints, but better still an arrangement consisting of three elbows.

The method of using the elbows is shown in Fig. 47; thus, if the ends *E* and *A* are fixed, the effect of expansion in the pipe *E D* will be to slightly unscrew the elbow *C*, and the lengthening of the pipe *A B* will also tend to unscrew the elbow *C*, but at the other screw thread.

The radiating surfaces are best made by connecting two large pieces of pipe called headers or manifolds together. It will not answer to connect these manifolds by straight pieces of pipe as shown in Fig. 48, for the reason that unequal expansion of these different lengths would certainly take place, in which case they would be broken, but an elbow must be inserted in each length of pipe so as to permit of independent expansion. The arrangement would be somewhat as indicated in Fig. 49.

The pipes that are used in steam-heating are then of two kinds, or, rather, perform two offices: One kind of pipe conveys the steam to the place where the steam is wanted; this we will call a steam main. The other pipes expose as much surface as possible to the cooling influence of the air, and their office is to give off heat; we will term these heating-pipes, and their outside surface the heating surface. We usually reckon heating surface in square feet, as it is much more convenient. Now we will get one square foot of heating surface with the following lengths of different sized pipes: ¾ inch pipe, 3.6 feet; 1 inch pipe, 2.9 feet; 1¼ inch pipe, 2.3 feet; 1½ inch pipe, 1.8 feet; 2 inch pipe, 1.6 feet.

It is evident at once that any escaping heat from main pipes is a loss, and should be prevented as far as possible by wrapping with material to prevent the escape of heat. The size of the main pipes, as we have seen, will have to be larger as they are increased in length.

With a drying kiln arranged in this way and with the pipes proportioned as explained there is no danger of failure, and the expense can be quite accurately estimated in advance.

The method of forcing an air-current over steam pipes at one end and putting no pipes under the dryer, is one that is even more economical in its results than the method given above. It will require much less heating surface and is certain to be successful.

STEAM DRY FLOORS.

A good method for drying brick is to employ an iron floor, flued underneath, the exhaust steam from the engine being turned under the floor loose.

In constructing a drying floor of this kind the following are good directions, which may be varied to suit special circumstances: First, lay down a bottom floor of any cheap, suitable material—hard, discolored brick and bats are as good as anything; lay this floor with a slight fall to an outlet or drain, so that the condensed steam may be properly conveyed away instead of being left to soak into the ground, as sometimes is foolishly done. When the floor is laid the joints should all be made tight with liquid lime poured over it and well ground in. About 10 or 12 inches above this the iron plates should be laid. The plates should be as level as possible, in order to make good joints and confine the steam. If of cast-iron they should be not less than one-half inch thick and not more than two feet wide; the length is limited only by the necessity of being straight and the ability to handle them. If of wrought-iron, they need not be over one-fourth inch thick, and may be two feet three inches or (possibly) two feet six inches wide. The walls to carry the plates should be chequered or perforated throughout so as to favor the free circulation of the steam—all but the top course, which must be solid. In laying down the plates they should be soundly bedded in good Portland cement. If the plates are of wrought-iron, the cross-joints should be laid on iron strips, from wall to wall, about three inches wide and one-fourth inch thick, bedded in cement same as other walls. If the plates are of cast-iron, they may be made with a lip on one end to receive the next plate, thus forming

the cross-joint. The manner of taking the exhaust steam to the floor depends a good deal on the width; if the floor is narrow, say not more than forty feet wide, the pipe may be taken across one side, close to the wall; the outlet for the steam should be about two inches, one under each row of plates, that is, about two feet or two feet three inches apart. If the floor is wider than forty feet, the pipe should go across the centre of the floor, the outlets of course being doubled—that is, a row on each side of the pipe—so as to throw steam both ways: as it is always possible that there may be some steam remaining uncondensed, its escape should be provided for by one or more outlets into the open air. With regard to the size of the pipe conveying the steam from the engine under the floor, do not pinch for room. In a long length of piping there is a certain amount of friction which should be compensated for by increased space in the pipe, so as not to put any back pressure on the engine. Always give a larger sized pipe than if the engine exhausted in the air; *i. e.*, if the engine would ordinarily need a five-inch exhaust pipe, give not less than six inches when taking the steam under the floor. In conclusion, I will say that a very little reflection is needed to see wherein consists the superiority of the steam-drying floor over other steam-drying systems. In the one the heat is obtained directly and immediately from the contact of the steam with the drying surface, whereas in all systems where the steam is confined in pipes the heat is obtained second-hand from the air warmed by the radiation from the steam pipes.

The above description is from an address delivered by Mr. A. Crossly, of Ironton, Ohio, at the second annual meeting of the National Brick Manufacturers' Association.

Exhaust steam from the engine can also be used advantageously by turning the steam into a gridiron system of steam pipes laid under a slat floor; air being admitted under the pipes, and by passing over them becoming heated, ascending vertically and passing out at the roof of the shed. By distributing steam pipes uniformly under the drying floor exhaust fans

are not necessary, as the heated air will rise and escape through openings in the roof without any artificial aid.

The quantity of air admitted can be regarded by suitable openings at the air inlets and outlets, and the temperature we think can be regulated in the same way, and also by suitable stop-cocks.

Of course there are minor detals to provide for, such as expansion and contraction of the pipe—drip, etc.

Care must be observed also not to have the openings in the roof so arranged as to cause a current of air to form in the centre or near the roof of the chamber and dry the brick which happen to be in the current, and not thoroughly dry those at the bottom, sides, or corners.

HOW TO DEVISE A DRYER.

Any person by devoting a little study to the subject, and possessed of even small ingenuity, can devise a dryer adapted to the particular clay to be desiccated.

It is not necessary to construct costly brick tunnels, as lumber is in many instances just as good as brick, and where a gentle heat is used answers all purposes.

Horizontal dryers are often made too long and with very short chimneys; not giving draught enough to draw the hot air to where it is needed. In such cases the chimneys must be heightened, or an exhaust fan used to draw the air through.

The early inventors of artificial dryers made the mistake of over-heating the brick or other wares, and thus making them porous and weak; besides, their outfit cost too much and required too much fuel. A mild heat (not above 150° F.) to aid in bringing the moisture to the surface of the drying brick, and just enough draught to carry forward the heat and take off the moisture, is what is required of a good artificial dryer.

A "FLUE" OR "HOT-FLOOR" DRYER

Brickmakers who want dryers and do not feel able to build those equipped with pallets, cars, tunnels, tracks, etc., can

construct a "flue" or "hot-floor" dryer with less outlay for material and labor than for any other form of reliable dryer. The following plan of construction is most durable and economical: The flues should be 150 feet in length between the furnaces and smoke-stacks. Grade the foundation for flues so that it rises 12 inches from the furnaces to the smoke-stacks. At the stack end let the flues open into a cross chamber, which connects them with the smoke-stack; this chamber should be as high as the top of the flues, and extend downward 12 inches below bottom of flues, and about 16 inches in width; this allows any soot that is not drawn into the stack to fall from the flue, thus preventing its accumulation in the mouth of the flue. At the furnace end the flues terminate and rest on a wall; here they receive heat from a distributing chamber, which in turn connects with the furnace; this chamber should be 16 inches wide, and about 6 inches higher than the top of the flues, and covered with an arch or large tiles; the bottom of the flues should be 12 inches higher than the grates in the furnace. These flues should be 5 inches wide, separated by four-inch walls, four courses high, either laid dry or laid in clay mortar, and covered with a brick on flat or on edge. These partition walls can be of salmon brick—the covers or cap-brick should be hard. The brick must be used about 6 feet from the furnaces, and the furnaces and chamber should be lined with fire-brick. These flues must be covered with tempered mud, and as it dries, roll it with a heavy roller, closing up openings caused by shrinkage; when too hard for the roller, use tamps, and tamp it until it is hard and nearly dry, then grout the floor with thin mud until dry and air-tight, then pave it with hard brick bedded in thin mud. The tempered mud should be put on so that when the floor is finished the whole thickness including cap-brick and pavement should be as follows: At the mouth of the flues next furnaces 12 inches, gradually reduced to 8 inches when half way to stacks, then gradually reduced to 5 or 6 inches at the stack. This floor, if properly constructed, will dry stiff-clay brick hacked close on end once every 48 hours, and will dry soft-mud

brick on flat once every 24 hours. The capacity of these floors with stiff brick on end is 10 brick per square foot, with soft-mud brick 2½ per square foot. With flues 150 feet long the smoke-stack should be 40 feet high at least. A stack of this height, with a flue 24 inches square inside, will answer for a dry floor 40 feet wide by 150 feet in length. A dryer of this size will dry 30,000 stiff-mud brick or 15,000 soft-mud brick per day. The roof can be put on with single comb, or a lighter roof with double comb, and a valley in the centre, supported by a row of posts through the centre of the dryer; these posts and all the others should rest on brick pillars, so that they are at least six inches above the top of the dryer floor; there is then no danger of fire being communicated to them from the flues. Most dryers of this kind that catch fire, catch from posts being buried in brickwork or in the ground near the flues. The building should be covered with a shingle, tin, or gravel roof. You must have something that is water-proof. A dryer roof that leaks is little better than none, as it damages brick and moistens the floor. The building should have eave-troughs and drains to carry away surface water, to prevent the flues next the side of the building from becoming damp and clogging with soot. When the flues need cleaning, make an opening across the floor into the flues, about every thirty feet, get a heavy telegraph wire of sufficient length, insert one end into a small plug of wood, and push it through the flues from one opening to another, fasten a bunch of old clothes to the other end of the wire, and drag it through one flue at a time. (After this bundle is drawn through once, it is dubbed "the black cat," which is appropriate.) In this way the flues can be thoroughly cleaned. The smoke-stack should be provided with a damper, so that it can be closed at night when fires are banked to hold heat under the floor. There should be a furnace about 3 feet wide and 5 feet long, with grates 3 feet in length, making 9 square feet of grate surface for each 8 feet width of dryer, that is, a dryer 40 feet wide would require 5 furnaces of the size mentioned. The slack-bin should extend at least 12 feet from

the furnaces. Coal slack will make all the heat required. When coal costs too much, wood can be used. The furnace may be the same size as for coal, but for wood only a few grates are needed in the middle of the furnace. Such a dryer will dry brick as well as the most costly kinds, but costs more for fuel to run it and for labor to handle the brick, as the brick have to be rehandled, while in the tunnel-dryers they go direct from the machines to the dryers on the drying cars.

DRYING BRICK BY A CURRENT OF HOT AIR.

Brick may be dried by a current of hot air, and in the following manner: The green brick as soon as made are loaded on cars and supported by a series of wrought-iron pallets, each car when fully loaded holding about 500 brick. A series of furnaces, with flues extending back the full length of the dryer, are built with their tops flush with the surface of the ground. Over each furnace a chamber large enough to hold six or eight cars is built. These chambers have a track laid in them, and are just large enough to admit the car loaded with brick.

The moisture and products of combustion are taken off in a chimney at the rear end. The green brick are put in at the farthest distance from the fire and moved forward toward the fire as they are dried. A transfer track should be so arranged as to permit the cars to be taken from any chamber and transferred to a single main track without trouble. On account of its separate chambers the construction of a dryer of this kind is necessarily costly, but these separate chambers are a necessity with any system of hot-air heating.

BUCYRUS DRYER.

Until a few years ago, the greater portion of all brick were dried in the open air.

One of the difficult problems for solution by brickmakers has been the successful drying of brick and other clay products.

The hot-floor, heated by coal fires, was the first artificial dryer known to the trade.

About 1864, the iron floor, heated with exhausted steam by day and live steam by night, came into practical use among fire-brick manufacturers. The next important step forward was the hot-air-tunnel dryer, heated with coal fires and smoke, so that when the brick came out dry, both the brick and the workmen had a negroid appearance, caused by the smoke and dust from the coal used adhering to the brick while in a moist condition. Aside from this objection, the danger of the buildings being consumed by fire was very great. The extreme wastefulness, and consequent cost of drying brick by this method, was the means of soon sounding the death-knell of this dryer.

In or about the year 1874 the steam tunnel dryer was first introduced, and at its inception was a very crude affair, being built without any provision for draft or circulation, and, owing to repeated failures, it was known by many brick-makers as a "sweating-box;" but, as the clay-working industry progressed year by year, and as the perfection of a more economical and successful dryer became the great desideratum of the trade, strenuous efforts were made to overcome the defects of the first attempt, resulting in various modifications of, and additions to, the original design.

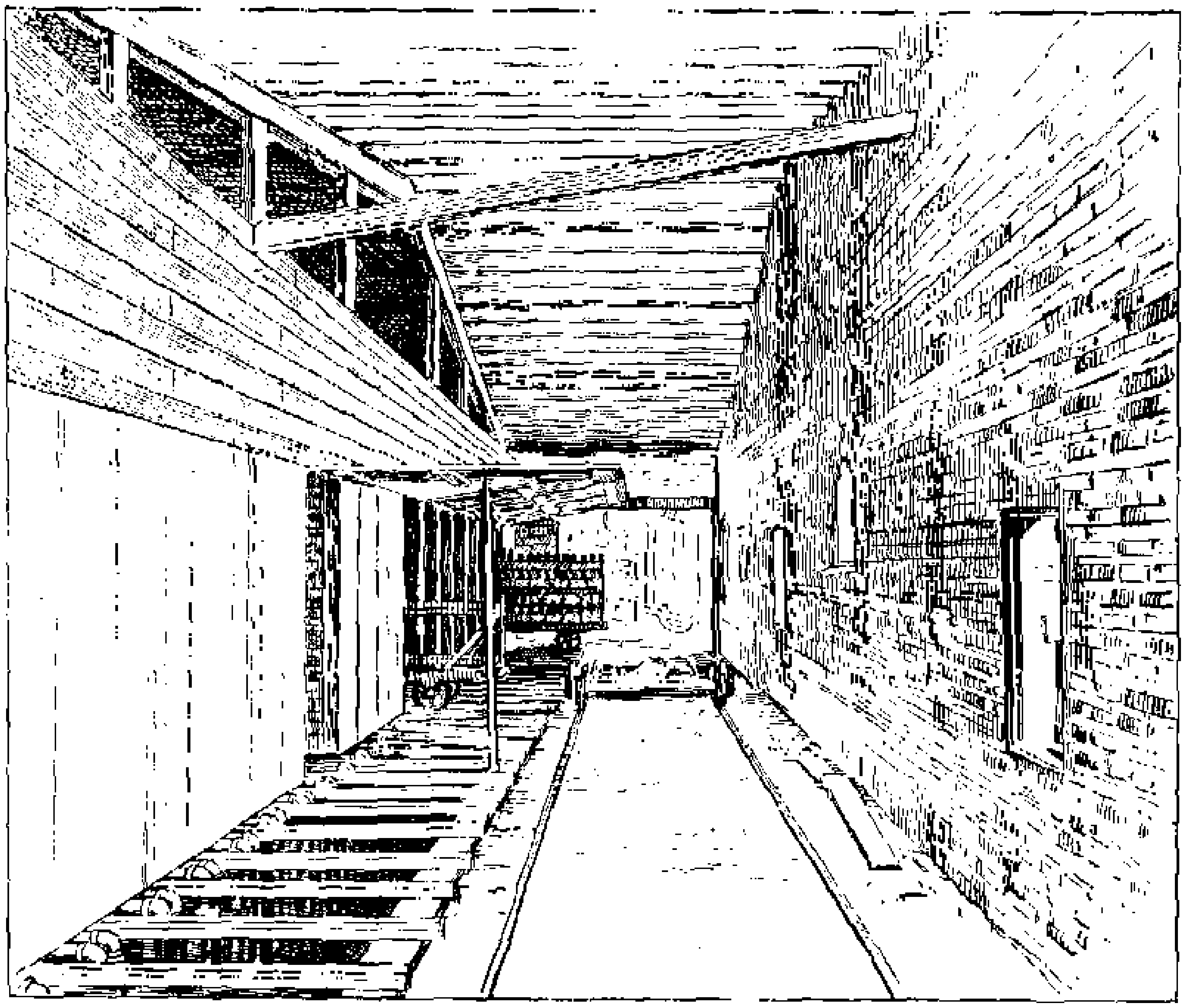
Another candidate soliciting the brick manufacturers' favor was the tunnel dryer, heated with coils of steam pipe, and the hot air circulated by a large revolving fan placed at one end. This process has, so far, not met with any perceptible encouragement, because of the fact that many clays will not stand the cyclone of hot air violently thrown upon its surface by the action of a fan, causing checks and cracks in the brick. The necessity of constantly keeping a man employed to operate a special engine day and night to run the fan proved to be one of the chief elements in destroying the usefulness and economy of this process.

A subsequent rival was the steam tunnel dryer, with natural circulation, effected by the use of air-ducts and one or two large stacks. By this method the whole amount of saturated air is drawn through and around the brick hacked in the end of

the dry-kiln near the stacks, super-adding moisture thereto, and tending to make the brick very fragile.

To overcome all the difficulties encountered by the foregoing processes, the Frey–Sheckler Co. were led to manufacture what is known as the "Bucyrus Steam Tunnel Dryer." The circulation of this dryer is as near perfection as it can be. Cold air is first admitted to the warm-air chamber in the

FIG. 50.



VIEW OF NINETEEN-TUNNEL DRYER. [From Discharge End].

"attic" of the dryer, and, after becoming heated, it is drawn into the tunnels by means of many warm-air ducts, and is discharged in the middle of the track, directly under the cars of brick, through a double series of hot pipes, by which the air is given a very high degree of heat. The air then passes upward, through and around the brick which are hacked on the car, and when the air is laden with moisture it is carried off by

the draft of vapor stacks, which at no point are over eight feet away. One of the many excellent features worth attention in this dryer, not possessed by any other, is that each tunnel is built entirely separate from the other tunnels, and, while all of the tunnels are under one roof, they are separated by division walls, and each tunnel can be operated independently, or in connection with the others, so that when one tunnel of brick is dry the steam can be shut off from the same. Then again, where large plants are erected to meet the requirements of large out-puts, and in case a reduction of the out-put is desired at any time, the dryer can be cut off to any desired capacity, as each tunnel is governed by its own pipes and valves.

There are a large number of these dryers in practical use by brick manufacturers, and they give satisfactory results. Fig. 50 shows a view of a Bucyrus Dryer, Nineteen-tunnel, (from discharge end).

SETTING BRICK IN THE KILN.*

All brick-makers recognize the importance of properly burning their wares. This cannot be done, however skilful the burner may be or how good the kiln, unless the brick have been properly set in the kiln; and much of the bad burning is due to ignorant or careless setting of the brick. A slight obstruction will change the course of heat, it being most sensitive. It is necessary that the spaces left for draft be, as nearly as practicable, uniform throughout the kiln. Where they are set three over three or eight over eight, the setter has a guide, and only by carelessness can he go wrong; but in the setting of the benches and overhanging courses he has no such guide and must use his skill.

Most setters hack the brick in the benches, that is, break joints. This is, I think, a mistake, as it prevents the heat from moving upward from the benches to the body of the kiln, so that all the heat must pass through the overhanging courses to reach the body of the kiln.

* From an article by R. B. Morrison, Rome, Georgia.

The benches should be set so that the heat can get into them from the arch or fire-flue and be able to pass freely from the benches directly upward into the kiln. I will illustrate my idea by the following diagram:

FIG. 51.

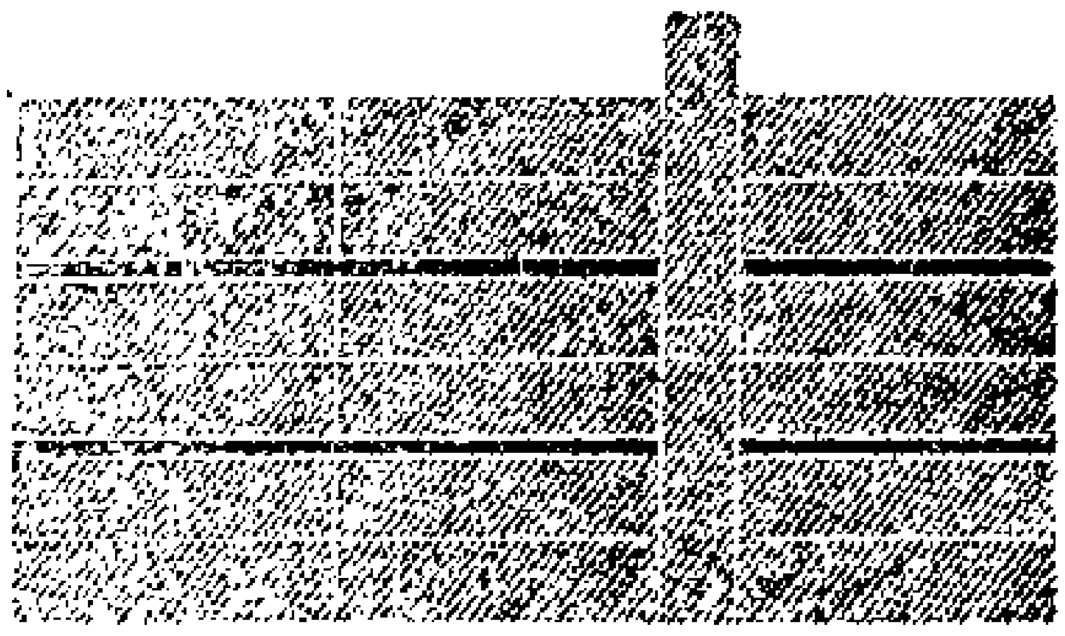
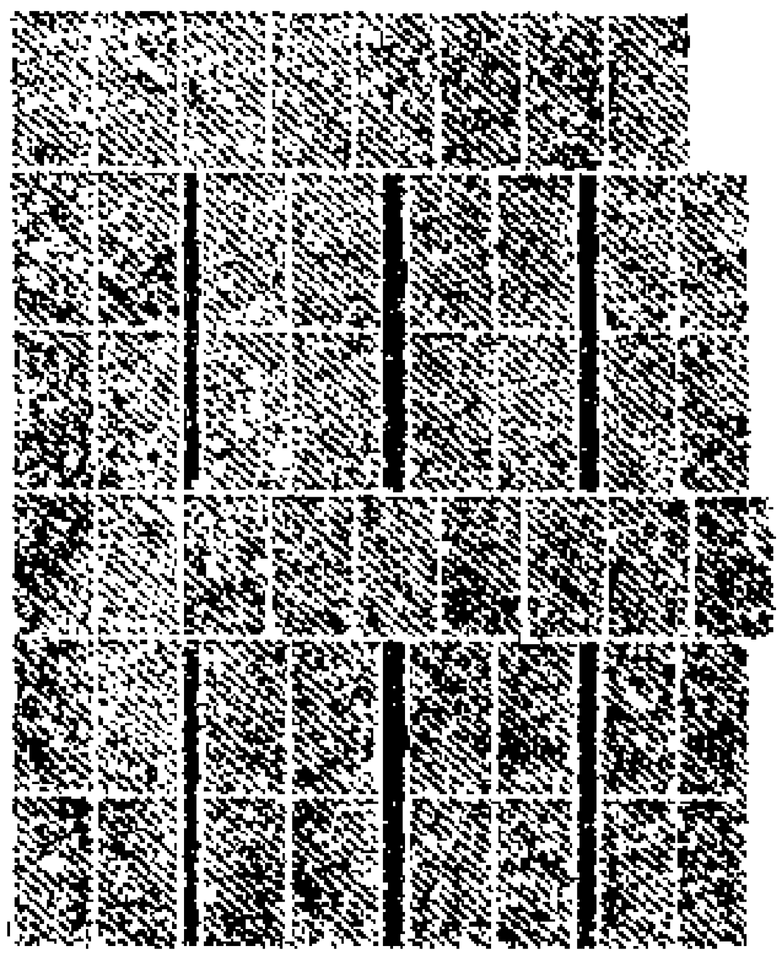
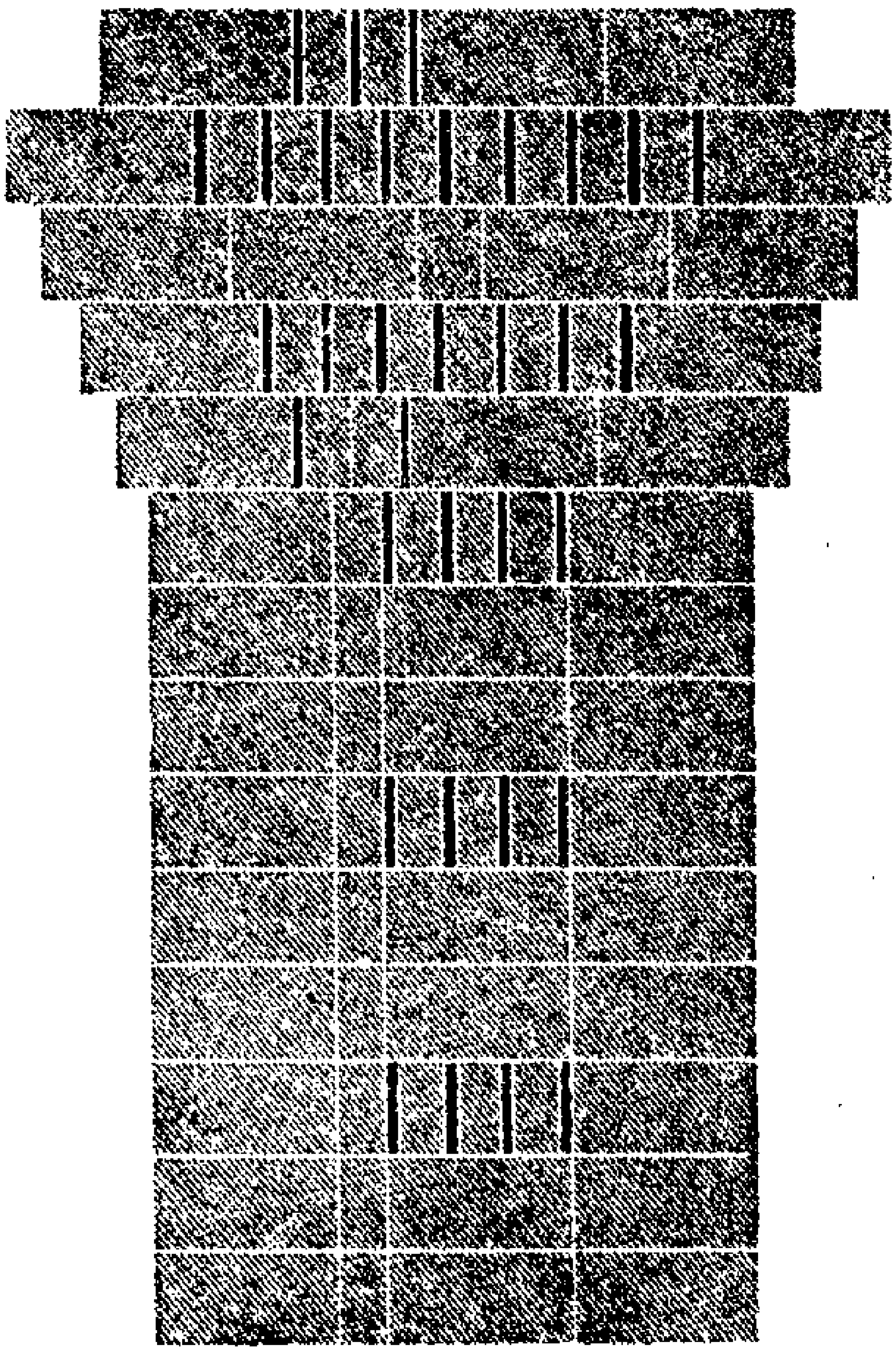


FIG 53.



ELEVATION.

FIG. 52.



ELEVATION.

Fig. 51 represents ground plan of the bench between eyes or arches of kiln. This is a three-brick bench with a stretcher between, known as a three-and-a-third-brick bench. The brick are set in pairs as shown.

Fig. 52 is the elevation of end view of bench, showing stretchers in third, sixth and ninth courses in middle course up to overhangers; then each alternate course in middle between overhangers in stretchers.

Fig. 53 is elevation of bench next to fire flue or arch showing first and second and fourth and fifth courses set in pairs, one directly over the other.

This shows only six courses. I think it better to set nine straight courses as shown in Fig. 52, the third, sixth and ninth courses tight as in Fig. 53; the third, sixth and ninth courses in middle bench, which are on a level with tight courses in bench next to fire, are set stretchers as shown in Fig. 52. This allows the heat to pass horizontally into middle bench, then vertically between the pairs and through stretcher courses into the kiln. When they are set in pairs they have one straight face. The stretcher between the courses from bottom to top prevents the fire from running from one arch to the other, as it will do when one arch is hotter than the other, but still allows sufficient circulation of heat through the bench. There is but one tight course above the bench, that is the binding course, which is immediately over the closing courses—one-half resting on each course. This is set tight only on the "quarters" of the kiln, and loose next to the wall and through centre of kiln. I think in setting above the arches they should be set with a little space for draft next to the wall and across each end. Set top course same as the balance, and use two courses flat, on top bottom course, crosswise of top edge course and one inch between brick, top course to be of good square-burned brick crosswise of bottom course and close together.

In the manufacture of pressed brick and of brick which are repressed after they come from the dry-clay or mud-brick machines, much depends upon the manner and care shown in setting the green brick in the kiln. The bottom must be level, and each brick exactly over the one it faces, and not projecting either sidewise or endwise, so as to have a perfect face. They must then be water-smoked and burned carefully, and the kiln settled level. They should be perfectly dry when set, and set on dry common brick to prevent whitening on the surface when burnt.

Some manufacturers do not use brick barrows or cars in moving the pressed or re-pressed brick from the dryers to the kiln, the brick when dry being placed on pallets, which are placed one on top of the other.

The wheelers take two pallets with twelve brick and carry them to the kiln on their shoulders; the setters take them from the wheelers, thus avoiding any chipping of the brick in the handling.

CARS USED IN HANDLING BRICK FOR SETTING.

In all works producing brick in large quantities by machinery, it is much cheaper in the end to place the brick directly upon cars and carry them to suitably constructed dryers, from whence they are carried to the kiln to be set.

The cars should be constructed of iron, and designed so that the slats can be turned up and over on the next one, and the "off-bearers" from the machine, and the "tossers" in the kiln can stand within the body of the car, close up to their work, for loading and unloading the brick. This is an improvement of far more value than would at first appear, for by standing so conveniently to the work, both to the off-bearing frame of the machine and to the hacks on the car, one hacker or off-bearer is enabled to perform much more work than he would do if compelled to lean over the width of the car.

The boxes on these cars are made with friction-rollers in them, and run without lubrication.

They should travel so lightly that a boy will transport four hundred and forty brick on one of them with greater ease than a man will push a wheelbarrow load on the best-designed barrow.

At each end of each of the flues of the dryer is a transfer or switching car, which transfers the loaded cars from a single track, running from the machine on to any one of the six tracks running into the flues; and in like manner from any one of the flues to the track running to the kilns.

The loaded cars are transferred into any one of the kilns of the works by means of transfer cars, and the empty ones returned to the machine by a return-rack, outside of the flues.

The whole of this arrangement may be under an inclosed building, and quite comfortable to work in at all seasons.

Altogether, the first cost of brick-dryers, cars, and tracks is more than for common drying-sheds and barrows, but the saving in the cost of handling the brick much more than compensates for this. The expense for fuel and attendance while the brick are in the dryers should not be charged wholly against them, as time and fuel are largely saved in the burning.

The advantage of running an establishment in all weathers, and twelve months in the year instead of eight, and having brick in the spring, when they command the best price, is too evident to need argument, to say nothing of the advantage to be gained in giving employment to your workmen the whole year round, and the difference in the cost of labor between winter and summer; but all of these advantages sink into insignificance when the superior quality of the brick is considered. The brick not being disturbed from the time they are put on the cars until they are run into the kilns, thus avoid two handlings in loading on the barrows for the two wheelings, whereby their shape and angles are preserved, rendering them much more perfect when burnt, and increasing their value in the market.

The dry car, shown in Fig. 54, is made by the Frey-Sheckler Co. This company manufactures its own cars, and guarantees the quality of material and work.

The frames are strong and substantially built, and provided with wrought-iron bumpers, which project two inches from each end to allow ample ventilating space between the cars.

The journals are of the roller-bearing type, as can be seen in the cut, and are far superior to the kind used by other manufacturers, obviating their defects and absolutely reducing friction to a minimum, thus producing an easy-running car, and prolonging the life of same beyond the usual limit. No oiling required.

The wheels are pressed on to the axles by hydraulic pressure, and are evenly gauged and nicely balanced.

The cars are thoroughly braced, so as to withstand all transverse strains, and will not go to pieces when subjected to hard and continued usage.

The Frey-Sheckler Co. make a car designed for carrying brick on foot pallets.

Length over all, 7 feet 3 inches.

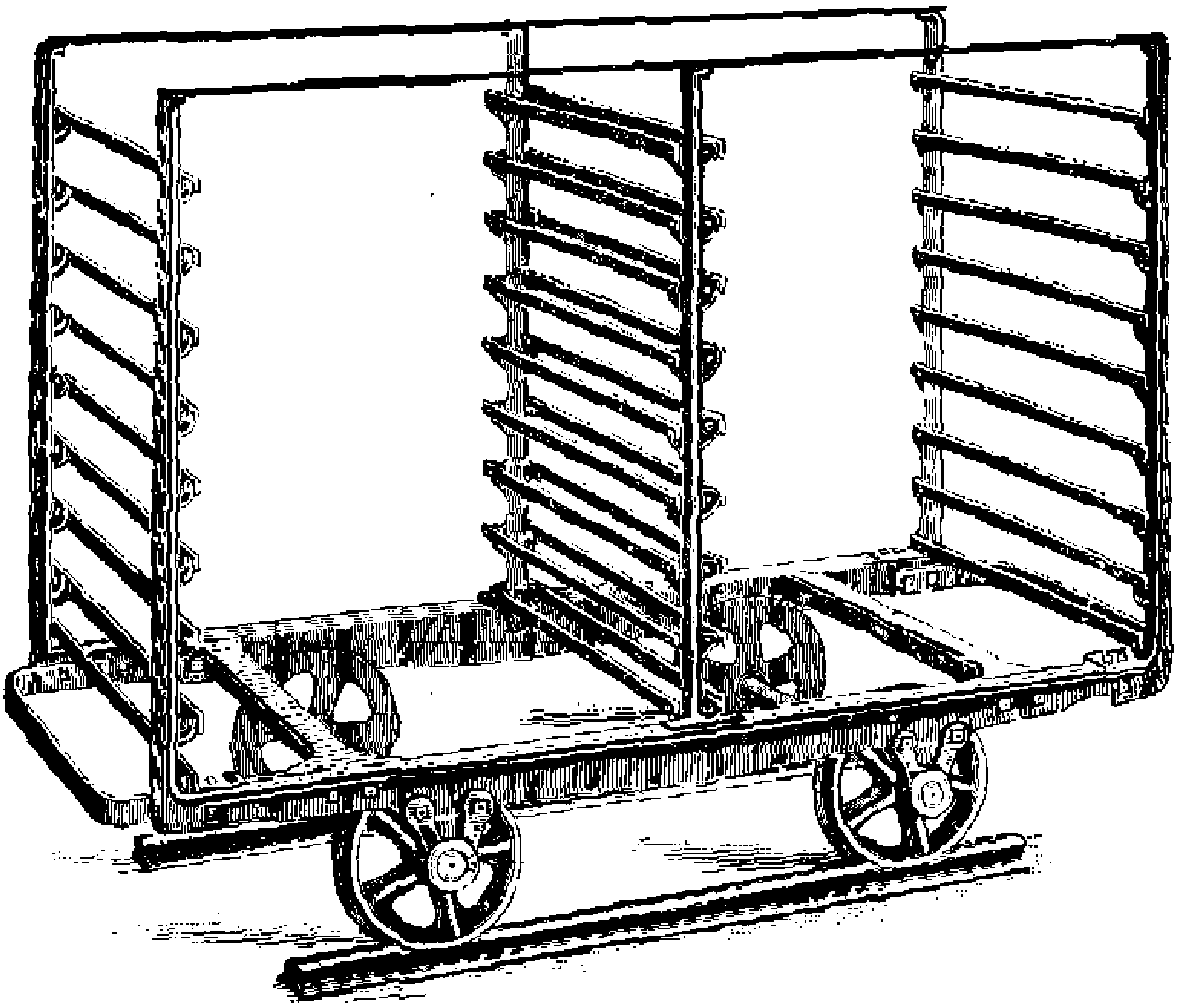
Width of frame over all, 35¾ inches.

Distance from centre to centre of wheels, 3 feet 6 inches.

Wheels 10½ inches diameter, 2-inch tread.

Gauge, 25 inches between track rails; weight, 320 pounds.

FIG. 54.



They also make a car designed for carrying all varieties of stiff-mud brick, being supplied with a double deck, equipped with angle iron upper deck frame, and as a binder for the wood slats.

Length over all, 7 feet 3 inches.

Width of frame over all, 35¾ inches.

Distance from centre to centre of wheels, 3 feet 6 inches.

Wheels, 10½ inches diameter, 2-inch tread.

Height from top of side frame to under side of top deck, 17 inches.

Size of angle iron for upper deck, 1¼ inches x 1¼ inches x $\frac{3}{16}$ inches.

Gauge, 25 inches between track rails; weight 425 pounds. Capacity 500 brick.

Fig. 54 shows a strong, serviceable and convenient iron rack pallet car, for carrying soft-mud brick; it has two rack sections. 34 inches by 40 inches, and hacks the brick 9 tiers high.

Dimensions are 6 feet 6 inches long, 40 inches wide, and 4 feet 7 inches high from track rail.

Gauge, 25 inches between track rails. Capacity, 432 brick. It is manufactured by the Frey-Sheckler Co.

WHEELBARROWS.

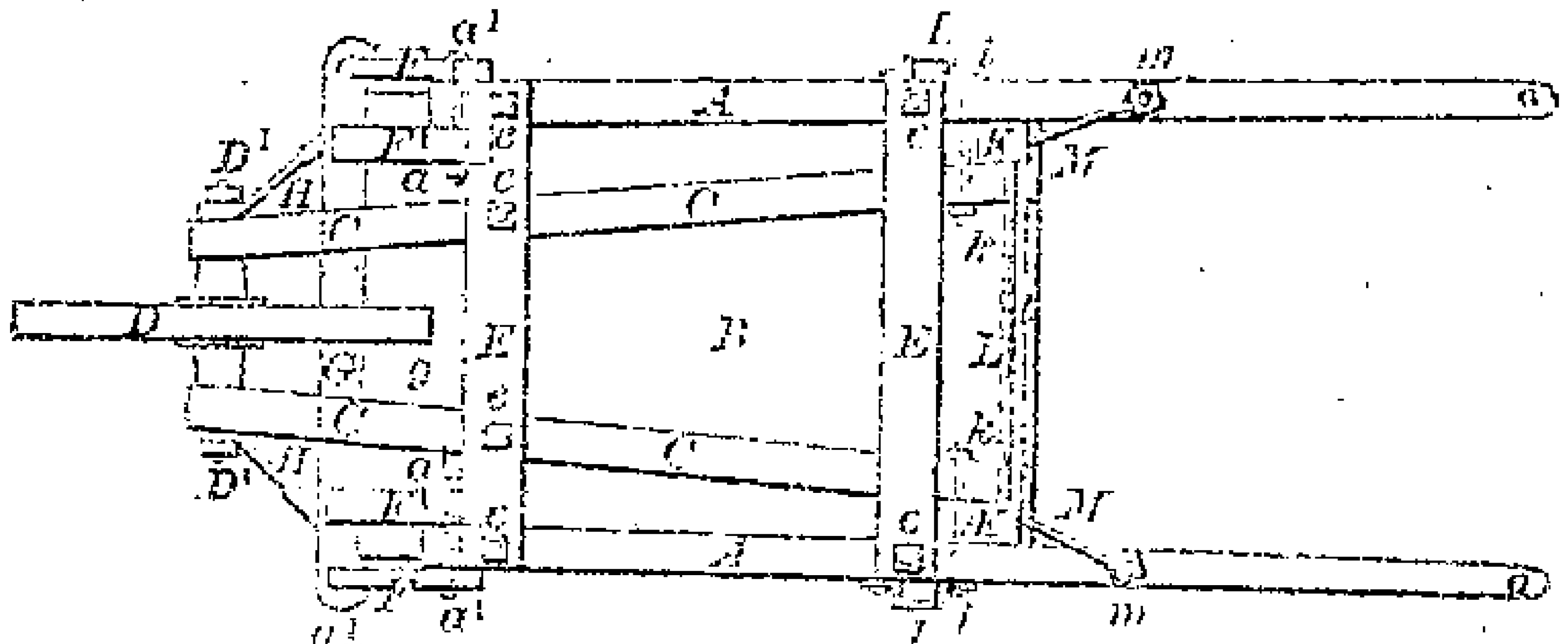
Wheelbarrows, which are important appliances of a brick-yard, are usually of one of three different styles of construction; one kind being for the purpose of carrying the clay from the pug-mill or ring-pit to the moulding table, which variety is called a "clay-barrow;" another is for wheeling the green brick from the drying-sheds to the kiln, and this kind is termed a "brick-barrow;" and the third is used for wheeling moulding sand to and from the drying-floors; this is called a "hopper" or "box-barrow."

In the clay-barrows the back is made slanting, so as to throw the weight of the clay well over the centre of the wheel; but in the brick-barrows the back is made so as to form right angles with the side bars, and the wheel protrudes through the back of the wheelbarrow about one-quarter its diameter.

The hopper or box-barrow has all its sides made on a slant of about 30°, being, of course, larger at the top of the hopper or box than at the bottom. A great many of these barrows were formerly made with wooden wheels, and had iron gudgeons, which worked in wooden boxes on the under side of the handles; but the majority of the brickyard barrows are now made with iron wheels, spindles and boxes.

Sometimes brickyard barrows are so constructed as to be easily folded up for transportation, or when not in use, and are employed and found useful for brickyard plants which require frequent changes, as for the construction of tunnels, culverts, etc., on the lines of railways and for other purposes. Such a barrow is shown in Figs. 55, 56 and 57, and it consists in certain arrangements of parts, whereby a very strong and cheap wheelbarrow is produced, which can easily be folded for economizing room in transportation, and thereafter be put into working order in a very little time.

Fig. 55.



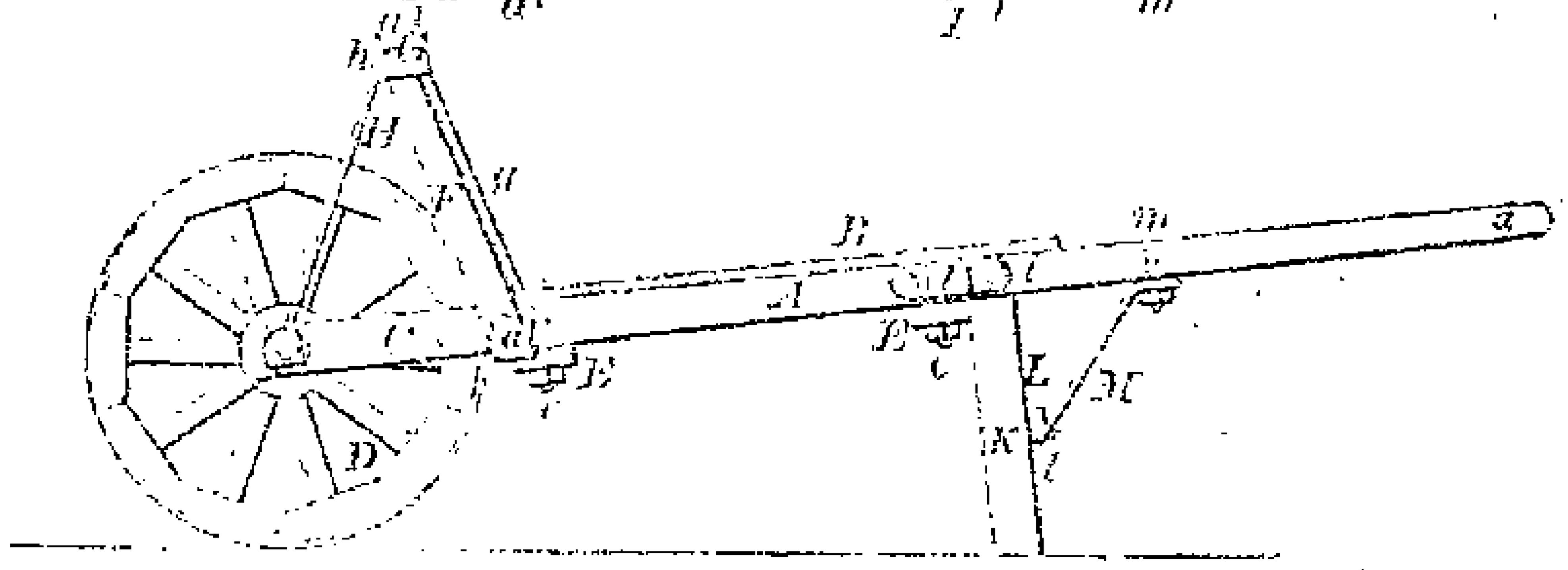


Fig. 56.

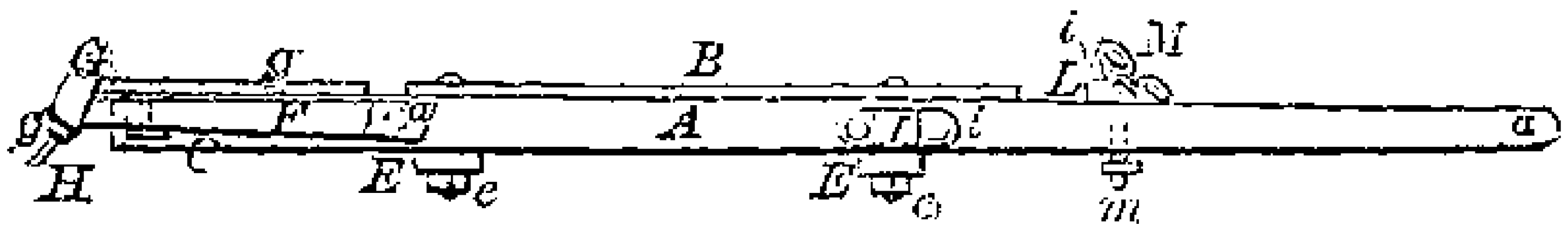
When it is desired to employ this form of wheelbarrow for handling brick, the back bars *F* should form a right angle with the side bars *A*, and the wheel *D* should be moved forward and cleave the back and bottom about one-fourth of the diameter of the wheel, in order to relieve the weight upon the handles, as in Fig. 58.

Fig. 55 is a bottom view of a folding wheelbarrow. Fig. 56 is a side elevation. Fig. 57 is a side view when folded up.

When the wheelbarrow is not in use, and is either to be stowed away or packed for transportation, the nuts are removed from the wheel-bolt *D*¹, the bolt removed, and the wheel *D*

taken off. The braces *H* are swung up until they meet on the inclined edge g^1, where they remain by means of friction. The back-board frame, with the back-board *g*, is now turned down upon the wheel-bars *C*, forming thereby an extension of the bottom *B*. The braces *M* are now disengaged from the bolts

FIG. 57.

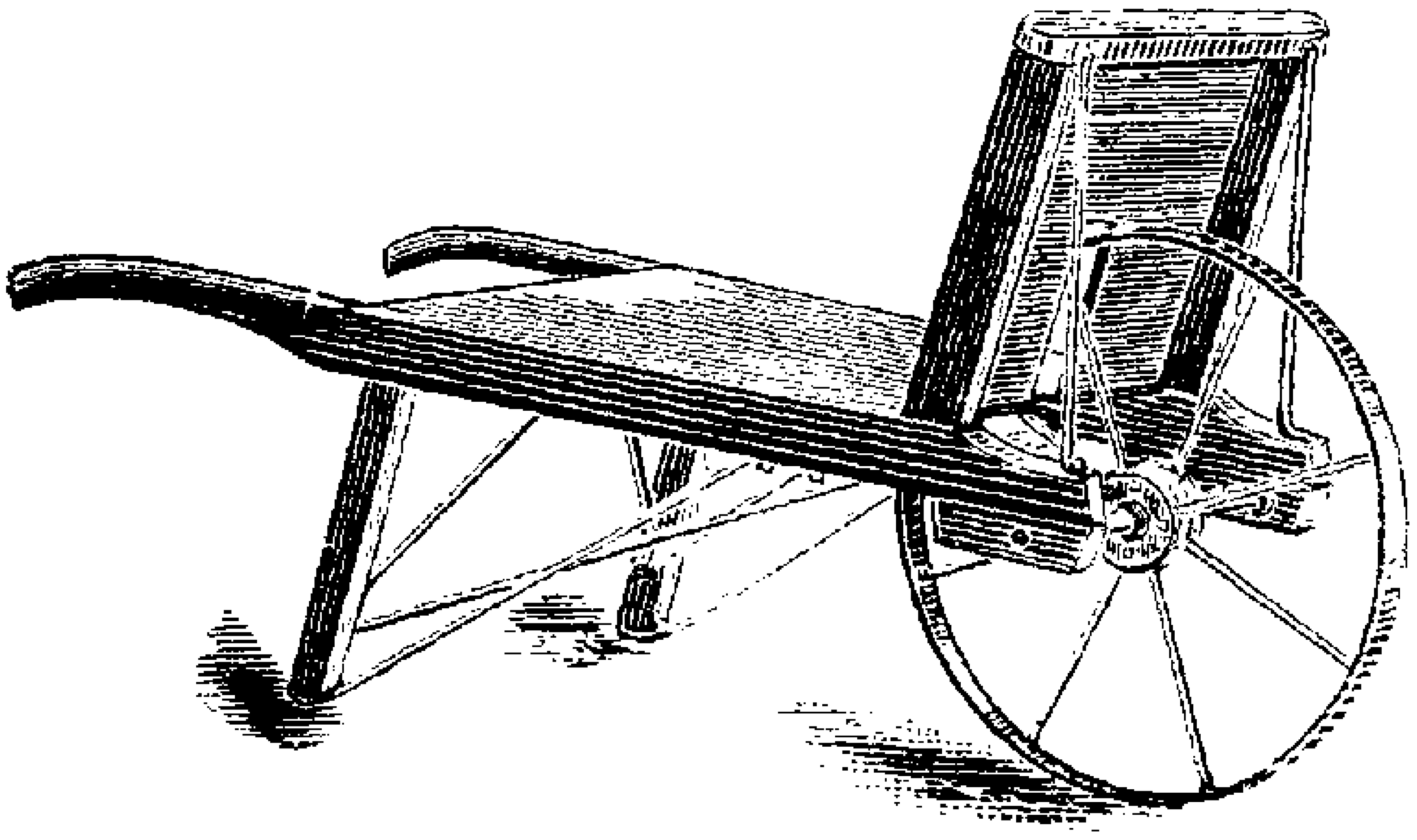


m, and folded together on the inclined edge *l* of the cross-bar *L*. Finally, the legs *K* are swung up between the side-bars *A*, and the folding up of the wheelbarrow is completed, as represented in Fig. 57.

To get the wheelbarrow in working condition again, the described operation is reversed. The folded wheelbarrow requires very little room for stowing away, and may be utilized for many purposes for which it is particularly adapted on account of its large platform.

The barrow shown in Fig. 58 is for wheeling brick, and it

FIG. 58.

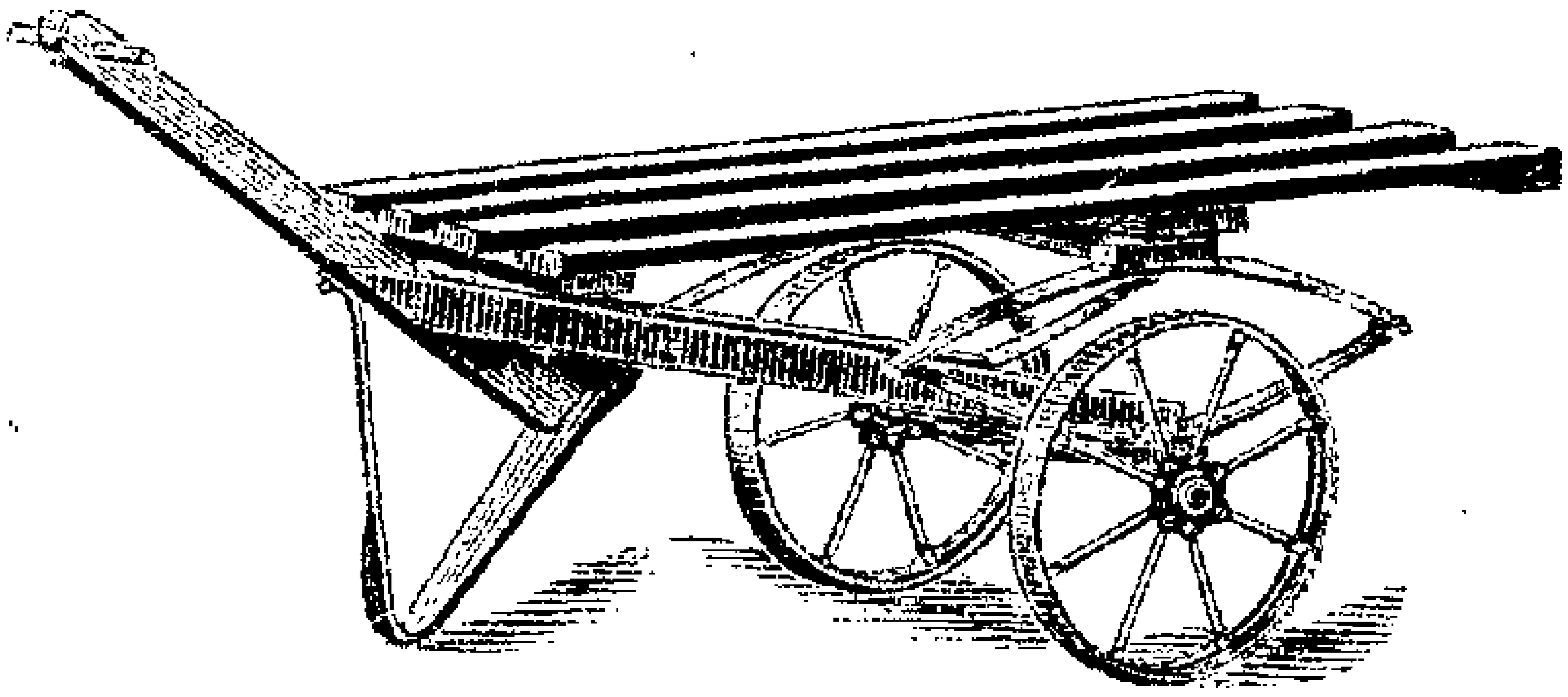


has a large malleable iron wheel, which is an aid to the laborer. The barrow is thoroughly braced, and is built so as to combine great strength with lightness of construction, and with ordinary care such a barrow should run and do good service for ten or twelve seasons.

The brick-truck shown in Fig. 59 is seldom used for handling hand-made bricks; but is employed for carrying machine-made bricks, and is usually built of two sizes, with either an open platform, as shown in the cut, or of light boards. The open top is used for carrying brick in the moulds, while the close platform is used for carrying them, as made ready for hacking or for conveying tile.

Of course, the manner of picking the brick up from off the cars, barrows, or trucks, whether one in each hand or two in

FIG. 59.



each hand, and tossing them to the setters, are details with which it would not be possible to deal, as local custom, nature of clay, and kind of bricks to be handled, must always govern.

BURNING BRICK.

In Chapter III. we have already described the method of burning hand-made brick, and as that method is analogous to the process employed in the burning of tempered-clay machine-made brick, no special description is therefore necessary.

We shall, consequently, in the present instance, confine ourselves to no regular description, but shall collate only such informamation as may be of practical value to the manufacturers of all classes of tempered-clay machine-made brick.

Fire is the chemically mixing of certain combustible substances with a supporter of combustion in such a way as to produce light and heat. Just what these elements are, and the most effective manner and means of bringing them together so as to produce the greatest amount of available heat, are among

the most difficult questions with which the practical brick manufacturer has to deal.

The most critical period in the process of brick-making is the burning of the kiln. Clay, sand, weather, and all other conditions necessary to the evolution of the perfect brick may be never so favorable, but without a successful burning all is failure. The burning with wood is both uncertain and expensive. These difficulties consist largely in the inability to control the heat, which is often unavoidably too high or low, and in the great cost of fuel and the labor necessary to care for a kiln after it has been fired. The arch brick are frequently much damaged by over-burning, the ends exposed to the fire being twisted, cracked, or even melted down, thus rendering them of little value. Then the percentage of soft brick, that is, brick insufficiently burned, is often a big item of loss to the brick-maker. These are found in the outside and upper courses.

NUMBER OF POUNDS OF BITUMINOUS COAL EQUAL TO ONE CORD OF WOOD.

Mr. W. A. Eudaly, of Cincinnati, Ohio, publishes the following statement of the number of pounds of bituminous coal that are equal to one cord of the various kinds of wood used in brick-making. Black hickory stands at the head. One cord of black hickory is equal to 1787 pounds of bituminous coal. One cord of white oak is equal to 1528 pounds, one cord of Southern pine is equal to 1354 pounds. It will thus be seen that pine ranks up pretty well. One cord of hard maple equals 1157 pounds, one cord of beech 1150 pounds. These are two of the favorite woods for brick burning. There are other reasons why they are favorites. They do not rank so high as fuel. One cord of hazel equals 1148 pounds of coal, one cord of Virginia pine 1075 pounds, one cord of New Jersey pine 854 pounds, one cord of cedar 764 pounds, one cord of yellow pine 768 pounds, one cord of white pine 747 pounds, one cord of spruce 674 pounds, one cord of hazel 496 pounds. There is another thing to be taken into consideration in figuring this wood. Pine is not the kind of pine, beech is not the kind of

TABLE SHOWING THE VALUE AND PROPERTIES OF VARIOUS KINDS OF COAL.

DESIGNATION OF COAL.	Weight per cubic foot by experiment.	Cubic feet of space required to stow a ton.	Volatile combustible matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 parts.	Pounds of steam to 1 of coal from 212° F.	Total waste in the state of ashes and clinker from 100 of coal.	Weight of clinker alone from 100 of coal.	Average weight in pounds of unburnt coke left on grate after each experiment.	Steam from 212° from 1 of combustible matter.
Beaver Meadow, slope No. 3 .... Pa.	54.93	40.78	2.38	88.94	7.11	9.21	11.96	1.01	112.4	10.462
Beaver Meadow, slope No. 5 .... Pa.	56.19	39.86	2.66	91.47	5.15	9.88	6.74	0.60	61.2	10.592
Forest Improvement .... Pa.	53.66	41.75	3.07	90.75	4.41	10.06	6.97	0.81	40.2	10.807
Peach Mountain .... Pa.	53.79	41.64	2.96	89.02	6.13	10.11	6.97	3.03	26.6	10.871
Lehigh .... Pa.	55.32	40.50	5.28	89.15	5.56	8.93	7.22	1.08	36.1	9.626
Lackawanna .... Pa.	48.89	45.82	3.91	87.74	6.35	9.79	8.93	1.24	57.2	10.764
Lykens Valley .... Pa.	48.56	46.13	6.88	83.84	9.25	9.46	12.24	4.40	18.0	10.788
Beaver Meadow (Navy Yard) .... Pa.	55.08	40.65	—	—	8.10	9.08	8.10	1.40	107.1	9.881
Natural coke of Virginia .... Va.	46.64	48.03	12.44	75.08	11.83	8.47	18.46	5.31	60.9	10.389
Coke of Midlothian coal .... Va.	32.70	68.50	—	—	16.55	8.63	16.54	10.51	53.2	10.343
Coke of Neff's (Cumberland) coal .... Md.	31.57	70.95	—	—	13.34	9.00	13.34	3.55	43.7	10.381
Mixture $\frac{1}{5}$ Cumb. and $\frac{4}{5}$ Beaver Meadow	54.29	41.26	—	—	8.88	8.86	8.88	4.91	9.5	9.725
Mixture $\frac{1}{2}$ Cumb. and $\frac{1}{2}$ Beaver Meadow	54.51	41.09	—	—	8.18	9.18	8.18	3.09	16.0	9.997
New York and Maryland Mining Company's .. Md.	53.70	41.71	12.31	73.50	12.40	9.78	12.71	5.43	10.1	11.208
Neff's Cumberland .... Md.	54.29	41.26	12.67	74.53	10.34	9.44	10.96	4.53	6.1	10.604
Easby's "coal in store" .... Md.	53.47	41.90	14.98	76.26	8.08	10.02	8.38	1.33	18.2	10.935
Atkinson & Templeman's .... Md.	52.92	42.33	15.53	76.69	7.33	10.70	7.96	2.12	5.1	11.624
Easby & Smith's .... Md.	51.16	43.78	15.52	74.29	9.30	9.96	9.69	3.04	5.3	11.034
Cumberland (Navy Yard) .... Md.	53.29	42.04	14.87	70.85	14.98	—	14.53	2.29	13.5	—
Dauphin & Susquehanna .... Pa.	50.54	44.32	13.82	74.24	11.49	9.34	16.36	3.50	23.7	11.171
Blossburg .... Pa.	53.05	42.22	14.78	73.11	10.77	9.72	11.20	3.40	13.7	10.956
Lycoming Creek .... Pa.	55.38	40.45	13.84	71.53	13.96	8.91	16.92	3.26	46.2	10.724
Quin's Run .... Pa.	50.34	44.50	17.97	72.79	8.41	10.27	8.94	1.31	14.7	11.275

TABLE SHOWING THE VALUE AND PROPERTIES OF VARIOUS KINDS OF COAL.—*Continued.*

DESIGNATION OF COAL.	Weight per cubic foot by experiment.	Cubic feet of space required to stow a ton.	Volatile combustible matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 Parts.	Pounds of steam to 1 of coal from 212°.	Total waste in the state of ashes and clinker from 100 of coal.	Weight of clinker alone from 100 of coal.	Average weight in pounds of unburnt coke left on grate after each experiment.	Steam from 212° from 1 of combustible matter.
Karthaus .... Pa.	52.54	42.63	19.53	73.77	7.00	9.09	7.89	3.66	52.5	9.887
Cambria County .... Pa.	53.46	41.90	20.52	69.37	9.15	9.24	9.75	3.48	14.8	10.239
Barr's Deep Run .... Va.	53.17	42.13	19.78	67.96	10.47	9.02	11.07	4.78	6.4	10.142
Crouch & Snead's .... Va.	53.59	41.80	24.38	59.98	14.28	8.34	14.34	5.37	6.0	9.740
Midlothian (900 feet shaft) .... Va.	50.52	44.34	27.28	61.08	10.47	8.58	10.70	6.47	5.9	9.611
Creek Company's Coal .... Va.	46.50	48.17	32.47	60.30	8.57	8.42	8.64	4.41	10.5	9.211
Clover Hill .... Va.	45.49	49.25	32.21	56.83	10.13	7.67	10.60	3.86	11.5	8.588
Chesterfield Mining Company's .... Va.	45.55	49.18	32.63	58.79	8.63	9.00	9.07	4.19	10.5	9.896
Midlothian (average) .... Va.	54.04	41.45	29.86	53.01	14.74	8.29	14.83	8.82	6.4	9.741
Tippecanoe .... Va.	45.10	49.67	34.54	54.62	9.37	7.75	9.72	4.03	11.2	8.583
Midlothian (new shaft) .... Va.	47.90	46.76	35.77	56.40	9.44	8.75	10.26	4.21	17.1	9.751
Midlothian (screened) .... Va.	45.72	48.99	34.70	54.06	9.66	8.94	10.27	3.33	14.8	9.970
Midlothian (Navy Yard) .... Va.	54.47	41.13	29.12	56.11	14.14	—	—	4.42	43.2	—
Pictou (from New York) .... N. S.	53.55	41.83	27.83	56.98	13.39	8.41	13.37	6.13	5.7	9.710
Sidney .... N. S.	47.44	47.22	23.81	67.57	5.49	7.99	6.01	2.24	5.9	8.497
Pictou (Cunards) .... N. S.	49.25	45.48	25.97	60.74	12.51	8.48	12.06	6.19	3.7	9.648
Liverpool .... Eng.	47.88	46.78	39.96	54.90	4.62	7.48	5.04	1.86	11.1	8.255
Newcastle .... Eng.	50.82	44.08	35.83	57.00	5.40	8.66	5.68	3.14	10.7	9.178
Scotch .... Scotland.	51.09	43.84	39.19	48.81	9.34	6.95	10.10	5.63	5.7	7.719
Pittsburgh .... Pa.	46.81	47.85	36.76	54.93	7.07	8.20	8.25	0.94	9.9	8.942
Cannelton .... Ind.	47.65	47.01	33.99	58.44	4.97	7.34	5.12	1.64	6.4	7.734
Dry Pine Wood	21.01	106.02	—	—	0.30	4.69	0.30	—	—	4.707

beach, nor cedar the kind of cedar that brick-makers are in the habit of putting into their kilns. The above analysis is made from thoroughly dry wood, not kiln-dried but well-dried wood. Some of the softer woods get moist, and they will run down much lower in the scale; but the above estimates are made on the basis of dry wood.

TABLE SHOWING THE VALUES AND PROPERTIES OF VARIOUS KINDS OF COAL.

On pages 180 and 181 there are given tables showing the value and other items of importance relating to different varieties of coal from Pennsylvania, Maryland, Virginia, England, Scotland, etc.

COAL SLACK FOR FUEL.

When coal slack is used for fuel in burning brick it is customary to use coke and wood for water-smoking, as a more regular heat is obtained, and when the water-smoke is off the firing is then continued with coal slack.

When the coal slack is of good quality it requires about 225 tons to burn 350,000 tempered-clay brick, and where the coal slack can be obtained for 75 cents per ton, the cost of burning, exclusive of that of water-smoking, is 50 cents per thousand.

RECENT PROGRESS MADE IN BURNING BRICK.

The progress recently made in burning brick has been almost as rapid as the improvements in the machinery, even if it has not reached the same perfection. We are indebted to Wingard, Morrison, Eudaly, and Melcher for their square-top kilns, and for superseding the old methods of burning with wood, which destroyed the brick in the arches, and was expensive. Owing to the scarcity of wood in many localities its use had to be abandoned. It would be almost impossible to burn all our yearly product of brick with wood now, as it would require annually 2,500,000 cords. This wood, piled four feet high and four feet wide, would reach over 3,700 miles in length. The round, or down-draft kiln, has merits for face or hard brick, but for large works the continuous kiln for burning common

brick is the most saving. Mr. Frederick Hoffman, of Berlin, is the inventor of this kind of kiln. They are in general use in Europe, over 100 of them being in England, and 250 on the Continent. Mr. Hoffman writes to Mr. B. W. Blair, of Cincinnati, Ohio, from whose address, delivered at the second annual meeting of the National Brick Manufacturers' Association, I have several times quoted in this work: "The principal advantage of my kiln is saving of coal. Ordinary brick kilns require about one ton of coal to 4,000 brick. Here in Germany about three-fourths of all brick made are burned in my kilns. In England the Royal Admiralty, as well as several railroad companies, have adopted them. The Russian government have adopted them at the fortresses of Brest-Litewsk," etc. We believe there are continuous kilns at Omaha, Neb., and Columbus, Ohio, but of their merits we are not thoroughly familiar. The cost of burning brick in the Hoffman kiln, where the cost of coal does not exceed $2.50 per ton, is about thirty-five cents per thousand. It is possible to melt the brick quicker in a Hoffman kiln than in any other, unless an experienced foreman is in charge. Natural gas, where it can be obtained, exceeds all other methods of burning. Experiments are being made with oil for burning brick, and also with artificial gas generated at the kiln. All attention is turned to burning now, and we may expect great improvements within a few years. What is now required is greater economy of fuel in burning brick, more perfect combustion, and even in many of the present improved plans there is too much waste of fuel and loss of brick from "spaulding" and melting together.

Even in the old open-top kilns, which by this time should be properly understood, there is great loss caused by improper firing; only enough coal should be thrown in at each firing to make a light coating all over the grate surface, say four dirt shovels full; the thickness of burning coke on the grates should not exceed four or five inches, and the grates be kept so as to show a bright light in the ash-pit at all times; and to save grates, hot coals should never be allowed to remain in the ash-pit.

There should be more space at the top for heat to escape while water-smoking than when settling a kiln, as the draft is less strong at first for the reason that the brick are cold and damp; as they become heated and throw off more heat, the draft becomes stronger, then the space on top must be reduced. This can be accomplished in an open-top kiln by the platting, the bottom platting being laid in strings one inch apart, the top platting crosswise of bottom platting and close together. While water-smoking a few rows of the top platting are raised, then as the heat begins to escape too rapidly, these are put in their place; another way is to lay top platting, leaving some space between them, then when ready to tighten they are forced together and other brick put in the spaces. The former plan is preferable, as it is less work to close up the top, and the heat can be controlled better while water-smoking with the first plan. In firing any of the forms of furnace kilns ordinarily immense volumes of black smoke continue to roll off for ten or fifteen minutes after firing, and when the kilns are so burned as to prevent the emission of the black smoke there results a material saving in the cost of burning, and it involves the question of water-smoking. Water-smoke is a product of heat coming in contact with the combined water that is in the material, the brick. If the brick be exposed to the sun, on hot days, like we have in July, and are allowed to stay there two or three days, covering them up over night to keep away the dew, then putting them in the kiln, they are not water-smoked. Why? Because all the combined water that lies between the little molecules of the clay does not evaporate in the atmosphere. When these are warmed up to 212 degrees then it becomes steam; and when water is turned into steam it increases in volume 1700 times. and one inch of water is 1700 inches of steam. This is one of the reasons why when we begin to burn this brick the brick begins to swell. Now, this water-smoke, as we call it, is turned into steam and passes away. If we undertake to raise the steam by putting in coal, it sends the carbon out of the top of the kiln in smoke and results in loss.

In order to prevent this loss it is best to fire slow when you first begin to warm your kiln. You save money by not being in too big a hurry when you commence firing—until you get up a temperature in the kiln. When you begin to burn there is very little draft; after it begins to warm and you get a heated atmosphere in the kiln, the more force has the draft.

After a kiln is "hot" to the top, the object then is to let the heat out of the arches as freely as possible, and hold it closely at the top. In this way the arches are not too hard, neither are there many pale brick under the platting. The heat can be driven rapidly out of the arches to the top by throwing air-currents of a moderate degree of heat into them.

It is more economical and also better to color the brick with a lively heat instead of a dead heat. When a kiln has a tardy draft the heat remains too long in the arches, causing the "headers" to melt and giving several courses of pale red or salmon brick on the top bench, and also consuming extra time. When there is proper draft and moving heat, the heat is nearly uniform from bottom to top and color of brick the same, and a better, brighter color than those burned with a dead heat: the latter are really baked instead of burned.

Practical brickmakers look at results rather than theories.

The hydrogen of the gases from coal and wood, and in the use of natural gas and artificial gas the oxygen necessary to supply combustion, are derived from the atmosphere. The hydrogen that is in the fuel has a greater affinity for the oxygen of the air than the carbon has; and if the furnace or arch, or wherever the fuel is burned, has not a proper supply of air, a sufficiency of it, the hydrogen will take up the oxygen and leave the carbon to pass in the kiln unburned. Now, many manufacturers of brick find in their kilns white brick, and gray brick, and striped brick, and laminated brick, for this very reason, and are not able to account for it. The carbon does not actually enter the body of the brick always. In the majority of cases, when the carbon is unburned in the furnace or in the arch, and passes into the kiln, it settles upon the brick, and when the

brick becomes hot enough, it partially burns, or burns into an ash. If the kiln or furnace be not of proper construction to burn the carbon in the furnace, and it escapes out without being burned, and is consumed in the kiln, which can be shown is the case nine times in ten, you are burning your fuel in your kiln on your brick, because it settles there, and it burns there, and it is liable to discolor the brick. It will not discolor all clays, because there are certain substances in the clay that hold the carbon and make different sorts of color. It cannot help but be so, and the idea that this carbon entered the body of the brick and caused it to swell badly may no doubt be correct in many instances. For this reason we know that generally in almost all clays where the ground bituminous coal is mixed with the green clay, and the brick put in the kiln and burned, it swells. The reason is this: The ground coal is placed in the clay, and when it is heated sufficiently, the volatile matter is thrown off; it must get out, and it simply swells the brick in the effort to escape. It is a mistaken idea that the gas in the coal can be consumed by getting it hot enough. It will not burn until air gets to it, and hence the gas is generated before the air reaches it, escapes through the brick, and for that reason the soft coal cannot be used.

BURNING BRICK WITH NATURAL GAS.*

The process of burning with gas is less simple than that of drying, and to be successfully accomplished requires a slight knowledge of the nature of natural gas, its action during combustion and the appearance of the brick whilst hot. The predominant element of natural gas differs from that of wood or coal. The analysis of most gases gives about 75 per cent. hydrogen, 15 per cent. carbon, and a small percentage each of nitrogen and oxygen. Naturally the products of combustion

* Partly from a paper read by Mr. D. C. Crowley, of Pittsburgh, Pa., at the second annual meeting of the National Brick Manufacturers' Association. Held in Jan., 1888. The conditions have now entirely changed, owing to the exhaustion of natural gas. C. T. D., March 4, 1895.

differ considerably from those of wood or coal; when the heated brick are observed through this atmosphere, the shade of color seems entirely different from brick at the same temperature in a kiln where other fuel is used. To this fact more than any other may be attributed the failure of several good coal-burners to succeed with gas. The greater affinity or uniting power which oxygen possesses for hydrogen over carbon is another stone over which many have stumbled. If from any cause there is a greater proportion of gas to air, the brick will be injured, as we shall see in relation to water-smoking and the early stage of firing. In water-smoking with gas, the process will probably require a longer period than with coal, in order to preserve the brick in their natural color and original form. If haste is attempted, the gas will not be thoroughly consumed, and the oxygen taking up the hydrogen frees the carbon, which being in minute particles seems to enter the pores of the clay. When the kiln becomes hotter, these particles are consumed, and act as if bituminous coal-dust had been mixed with the clay. The brick become spongy, blackened and run together in a mass. Where this has occurred, I have seen ordinary sized brick in the bench misshapen and extended to a length of 15 or 16 inches. Often, when the draft is not good, the carbon will be deposited in considerable quantities in the form of coke in the bottom of the arch furnace. This usually occurs from the improper admission of the air, which should enter the arch in such a manner as to thoroughly mix with and consume all the gas before coming in contact with the brick. In fact, in the proper admission and control of the air-current entering the furnace or arch is contained the secret of successfully burning natural gas. In ordinary kilns, and without the aid of costly burners and by utilizing only the most simple and inexpensive contrivances, the brick can be burned thoroughly, without discoloring, and from wall to wall and from bottom to top, except the last course. Certainly to do this requires careful watching and delicate manipulation of the air-currents from the moment the water-smoke starts until the kiln is closed, but the waste

and soft brick in such a kiln are a very small percentage when the undertaking is completed, which with ordinary clays is about three days. One day should be used in heating the kiln throughout a perceptible red, another in settling the sides, a third the middle, and the last in bringing to terms any spots that may have remained. Seven days are thus occupied from lighting to closing, but some difficult clays, or clays that demand a tender handling, will require a longer time, whilst others can be done in a much shorter period. As an example of the difference in clays, not long since I secured a sample of bluish clay from Haverstraw, N. Y., took another from the light, loamy clay near Pittsburgh, and had them both worked up and burnt beside the strong plastic clay of the Wittmer Brick Co. After keeping them at a moderate heat for some time they were allowed to gradually cool, and when taken out we found the Haverstraw clay closely fused and distorted in shape; the loamy clay was somewhat past color, having a bluish tinge; whilst the Wittmer clay, though withstanding a greater resistance before fracture, was only a fair salmon. Where color and uniformity of shade are an object, a longer time will give better results, the heating should be more gradual, and the settling less rapid. When to cease firing must be judged almost entirely by the degree of heat. There is no blue smoke with gas, and the settle is not always a safe guide. I have seen clays with 18 inches settle having seven courses of soft brick, whilst in other burns the same clay with 18 inches settle gave good front brick in the second course from the top. The best indication in the up-draft kiln is the intensity of the heat at the top. With a little experience and a knowledge of the clay, the burner can judge from this to a nicety. In down-draft kilns, of course, the heat is judged by aid of the peep holes and test brick.

Natural gas is applicable to all manner of kilns now used. It has been most successfully applied to the up-draft pattern, with or without furnaces. Those without furnaces are probably to be preferred on account of the tendency of the gas to rise to

the roof of the furnace and follow it and the inner wall to the brick before it is thoroughly consumed. The Wittmer Co., of Pittsburgh, uses both patterns. The kilns have 20 arches each, with 4½ brick to the head and 39 brick wide, holding in the neighborhood of 375,000.

The old kilns in which the slack was used have 3-foot furnaces, whilst the new kilns simply have openings 9 by 24 inches in the 20-inch wall. The results are about equal, the brick being hard to the walls, and to the top, except one course, and free from whitewash or fire-marks, but in those having furnaces the overhangers near the wall are slightly discolored, while in those without furnace only a half dozen brick near the bottom will be slightly bluish. Gas is successfully used in down-draft kilns, especially for burning tile and terra-cotta ware. In these the brick or ware are uniformly burned, but there seems to be a slight tendency to over-color. I do not know if natural gas has been applied to continuous kilns, but feel confident that it would succeed in them. However, they will scarcely come into general use where this cheap fuel is employed, because of the ease with which it is applied and handled in ordinary kilns. With regard to the cost of burning with gas, it varies according to the situation of the yard. If the owner should be fortunate enough to possess a gas well, he would be at only the actual cost for drilling and fitting. Should the yard be situated on a line that is anxious for custom, or where there are competing lines, the gas may be had very reasonably under such circumstances. Even under these unfavorable circumstances the brick manufacturer is a gainer, as he saves the cost of labor in hauling, handling, stoking, and moving the refuse of other fuels, and has a superior quality of brick with less waste. One person can handle all the kilns in a yard by firing hard during the day and easing up at night. The salary paid to gas-burners is considerably above that paid to others, but it is a small item compared to the aggregate wages paid to the army of men whose services are dispensed with. A great amount of space that was required for

stacking and storing coal is also free to be utilized for other purposes, and a yard can work the year round, without annoying the neighborhood or injuring property.

Mr. J. R. Boice was one of the first to use natural gas on its introduction in Toledo, Ohio, and its results have proven satisfactory with kilns holding even as many as 1,000,000 brick each, the cost of burning being about forty per cent. less than with coal, and the quality and color equally as good as with either wood or coal. Mr. G. B. Smith, of Haverstraw, N. Y., in speaking of the use of gas made at the kilns by his firm as a fuel for burning brick, said:

"The cost of burning brick in Haverstraw with soft coal at about $2.50 per ton averages from 85 to 95 cents per thousand for the fuel.

"The idea of burning brick with gas was new to us. We have had but very little trouble in applying it, and our burners have acquainted themselves with it very easily. We are now burning our brick at a cost of some 50 or 65 per cent. less than with wood, and the saving of labor is still greater than that.

"It costs between 30 and 40 cents a thousand to burn brick with gas. We burn a very wide kiln, set 49–50 wide.

"We burn the open-hearth kiln, manufacturing the gas at the mouth of our arch. A pipe runs under the kiln, supplying the liquid carbon, and the steam is supplied from our steam boilers, and the gas is generated at the mouth of each kiln and burnt green. We actually get the same gas they manufacture for town service—hydrocarbon gas. We get the gas with steam. We can carbonize it with any liquid carbon. We are using a residuum which we get from the refineries in Ohio—a crude oil, after the laminated oil and naphthas are taken out of it. We want carbon only in a liquid. Any substance that contains a larger per cent. of carbon is the article we want. Tar answers the same purpose where it can be got cheaply.

"The gas requires to be carbonized, because we cannot burn hydrogen without carbonizing it; if hydrogen could be burned alone in the kiln, it would be the cheapest fuel. Of course, we

get it in steam, decomposed by the heat of the furnace, superheated by steam. Our steam is made into hydrogen where it enters the mouth of the kiln. By carbonizing it we get our combustion from a natural draft supply of oxygen, but hydrogen alone with natural draft would not give us combustion in an open furnace.

"The cost of wood averages from $5 to $5.50 per cord at Haverstraw, N. Y., and the saving in cost of fuel, using gas instead of wood, is from 50 to 65 per cent. In many portions of the country the cost of wood ranges only from about $1.35 to $2 per cord, and in such instances wood is the cheaper fuel. In the cost of burning by gas, as stated above, we estimated the cost of wood in opening the draft, but not the cost of labor, which is a separate item. The size of the brick produced by us is 8 inches long, 3½ wide, 2¼ thick.

"It is difficult to say whether or not this process with wood at $3 a cord and best Indiana or Ohio coal at $3 a ton would be a cheaper process of burning brick, taking all things into consideration, labor and everything.

"There is the question of clays used in different localities. The quantity of wood required to burn some clays is much greater than others. It would depend upon the cost of oil and the cost of transportation. In the State of Ohio oil can be obtained for about one-half of what it costs on the Hudson river. With our clay and conditions I think the cost is less with oil at present prices than with wood at prices named. We have used very little coal there. The price of crude oil at Haverstraw is about $1 a barrel.

"Two burners at a cost of $160 are required to an arch. The burners are used for two-and-a-half to three days on a kiln, so that the burners would do work in a week's time double that of the old process."

BURNING BRICK, TILE, ETC., WITH CRUDE OIL.

In the burning of brick, tile, etc., with natural gas, the principal obstacle to be overcome was the tendency of the tubes

carrying the fuel to become choked at the outer end, where they came in contact with the heat, by the escape of the more volatile substance and the deposit of the solid matter in the pipe. To obviate this, it was proposed to throw the petroleum into the arches in the form of spray. To accomplish this, two methods have been proposed, compressed air and super-heated steam. Either will produce the effect, and with proper care a good burn may be obtained; but it is observed that when air is the spraying agent a portion of the carbon is deposited under the arch, in the form of solid gas carbon, while no such thing occurs when steam is employed. Why this difference? It will be found in the different chemical compositions of the two agents. Air is only about one-fifth oxygen, and when it has contributed enough to burn the hydrogen of the petroleum and a portion of the carbon, the oxygen is exhausted and the unburnt carbon is deposited—a lost material. On the other hand, steam, being atomized water, is eight-ninths oxygen by weight, and as soon as it strikes the burning hydrogen of the petroleum, both in the form of spray, the hydrogen is detached from the oxygen to join that of the petroleum, and the oxygen is liberated, and proves sufficient for the perfect combustion of all the carbon; hence none is deposited.

Mr. Chas. S. Purington, of Chicago, Ill., commenced to use petroleum as a fuel in the dry-houses, and so successful did the experiment prove that no other fuel has since been used by him for drying brick.

The Dye dryer was the one employed by Mr. Purington, and the fuel used prior to petroleum was coke, which, including labor of running the dryers, and handling the coke and ashes, cost about 37 cents per thousand; but by the use of the petroleum the cost of drying was reduced to 20 cents per thousand brick, including all labor that is incident to the drying of brick.

The time necessary to dry the brick was reduced by the use of oil as fuel from 10 hours to 8 hours, this saving of time being of itself a great advantage, as the output of the works could be increased 20 per cent. without any increase in the drying capacity.

Mr. Purington, speaking of the use of petroleum as a fuel in a paper read before the Indiana Tile and Drainage Association, said:

"This expriment with our dryers proving so successful, the question arose, 'Why not burn brick with oil?' We spoke with several fuel oil experts as to the feasibility of so doing, but they all thought it could not be done without permanent kilns, which we did not have. Unmindful, however, of their apprehensions and our own fears, we determined to try it. As a result of bad burns with wood and coal, we had in our yards quite a number of salmon brick; of these we made a small kiln of three arches, adjusted our burners as seemed best, turned on our oil, and at the expiration of 36 hours we had converted the salmon brick into good, hard, merchantable material. We then made a three-arch kiln of green brick, and burned it in 62 hours. These brick were very good, but there were a few swelled brick in the centre of the kiln. I thought at the time it was caused by not drying off long enough, but since then I have concluded it was caused by putting coal screenings into the brick, as we were obliged to do in burning with wood and coal, but we have not used any more screenings since we commenced using oil. We have since then burned one six-arch and one eight-arch kiln, both of which were very successful.

"The cost of burning was from 35 to 50 cents a thousand cheaper than by the old method.

"The brick were better than ever before burnt in our yard, and the waste was almost nothing.

"The burners used on the first two kilns were the Smith & Spaulding, and the Hildreth on the last two.

"The main point to be attended in burning with oil is, to burn up all the petroleum. I have not seen any burner that made a perfect combustion of all the oil that went into the arch; that is, small particles of oil would fall upon the ground in the form of sparks, and there form a cake as hard as glass when cold. This, I believe, is wasted fuel; and when this can be overcome there will be a great saving in the fuel used. My

foreman is now working and experimenting on a burner of his own construction, and I am almost convinced in my own mind that he has struck the key-note of the problem.

"The steam used by us came from our engine-boilers some 600 feet distant and required considerable super-heating; but where a boiler is near the kiln I think super-heating unnecessary. For a ten-arch kiln it would require about a ten-horse power boiler. This could be moved along the shed from kiln to kiln as required.

"I have now given you my experience in the use of fuel oil.

"The conclusion I draw from its successful use under the dryers is that it makes a steady heat, enabling us to regulate its degree of intensity from the time the brick or tile go into the houses green until they come out dry. There is no smoke or soot to clog the flues, and the steam continually blowing into the furnace gives us at all times an excellent draft. Two men, one at night and one in the day-time, can attend to the drying, while with other fuel it takes from four to five men to do the same work. Two men can easily dry 200,000 brick in 24 hours just as well as they can 50,000.

"As to the burning of brick I can only speak of our own clay—a very difficult clay to burn right. From the time we start to burn until the finish we must continually force our fires. We only dry off twelve hours. With wood and coal it required much labor and constant care, but with oil and careful attention we can maintain a steady heat at any required degree, and you can manipulate it in such a manner as to give any part of the arch the heat required.

"The kiln never chokes, and cold spots are unheard-of things. You can hold your fires at any point. On one of three kilns we held the fires on the head in the face of one of the severest storms that has blown over Chicago for years—a gale that lasted eighteen hours—and that head was so hot you could not touch it with your hand.

"The oil which we use is obtained from the great and inexhaustible fields of Lima, O.

"It costs, with wood and coal, from 80 cents to $1.25 per thousand to burn my brick; with crude oil it costs 40 cents per thousand. I have been using four brick-benches, and I am sure I could use six brick-benches. There is a great saving in the labor required to fire the kiln, and the brick are well burned throughout.

"The steam atomizes the oil, or it should do so.

"To begin, build a little wood fire to start the flame, and put one burner in each end of the arches of 27 feet in length, and it is possible to properly fire an arch 50 feet long. Use 40 pounds pressure of steam. There is no difference in the color of brick burned with oil as compared with those burned with wood or coal.

"Use oil stored in a tank placed higher than the burners, and use a cock to gauge the amount of oil for the burners."

Mr. S. P. Crafts said, at the Third Annual Convention of the National Association of Brickmakers:—

"One cord of beech wood, worth $4, contains 17,065,000 heat units; one ton of bituminous coal, at $4, contains 31,227,000 heat units; four barrels of fuel oil, 40 gallons each, at $1 per barrel at 6 pounds to the gallon, gives us 20,160,000 heat units.

"Here, then, we have data based on the cost and heat values for Southern New England, the variation from which will not be large for any of the brick manufacturing centres in that region, in which I include the Hudson river, New Jersey, etc.

"Now, which fuel shall we use? The greatest cost for labor in burning and the least cost for fitting up is with wood, but it involves the largest cost for fuel. The maximum cost for fitting up and the minimum cost for labor in burning is with coal, but with the least cost for fuel if all the heat which it contains can be utilized. With oil the cost of fitting up is more than with wood, but less than with coal. The cost of burning with oil is less than with wood but more than with coal, unless a much greater per cent. of the heat of the oil can be utilized than that of coal. Now it is claimed that all the heat there is

in the oil can be obtained, at least 19,000 out of the 20,200 units, and that with coal but 8,000 or 8,500 out of the 14,300 units. These are claimed as proportions in the pound weights of the two fuels. When we consider the cost, they more nearly approach each other. 12 pounds of oil cost 5 cents, and 12 pounds of coal cost 2¼ cents; therefore to get at the relative values we must estimate the work of 12 pounds of oil and the work of 28 pounds of coal; 12 pounds of oil at 19,000 heat units gives 228,000 heat units as against 224,000 at 8,000 or 238,000 at 8,500.

"From this it seems that there is very little difference between the cost of coal or oil unless some other consideration intervenes. But there is a consideration of the lesser expense of fitting up for oil, the saving of time in burning, the fewer hands required, and the ease with which the heat can be increased. You may keep your brick at a dull-red degree of heat for any length of time and fail to burn them hard: but if you can, in a shorter time, with oil, get the requisite temperature, then you do the work in less time and at a saving of fuel, for the radiation of the heat of a kiln in six or seven days is no small item. It seems to me that in this shortening of time and saving thereby is the principal argument in favor of oil over coal; but it becomes us to consider whether the difference of the percentage of heat utilized under a boiler when burning oil or coal will hold good when diffused in and through a kiln of brick. I do not think it will, for a kiln seems to take up all the heat of combustion in either case, certainly until the last stage of burning, when the blanket of steam ceases to hold down the heat as in the earlier stages, a condition very different from the smoke-stack of a boiler.

"Wood is the simplest and most expensive fuel in most localities, certainly in localities where the greatest number of brick are made, but between coal and fuel oil it is an open question yet to be determined which is the better, by a longer and more thorough test.

"I have used coal at a cost of about 50 cents per 1,000, and

am now trying oil in the latter stage in burning to get a larger volume of heat and to deepen the color of the brick when burned. We have just finished burning a kiln of 19 arches, containing 451,000 brick, using 67 tons of coal at $4.25 per ton, making the cost per thousand 63$\frac{6}{10}$ cents. This kiln of 451,000 brick contains 15 tons of coal-dust as against 18 tons in the same number of brick made last year. This amount and the height (six brick higher than last year) may account for the longer time and greater relative consumption of coal than usual; two hands do the work. We set 52 brick high to economize the shed room, but are satisfied that 46 high is better and more economical.

Mr. D. V. Purington, of Chicago, Ill., said at the third annual convention of the National Association of Brickmakers: "I have burnt this year, 1888, a little over 28,000,000 brick without using a stick of wood or a pound of coal—entirely with oil. Of course, my brick are artificially dried. We have taken out of each brick, from the time it was made till it was set in the kiln, a pound and a quarter of water, so they are when set about as dry as can be got, practically. We start one side of the kiln three or four hours before we do the other, and we get the heat up just as fast as we can get the draft started. When we first start, of course, without the arches being heated at the sides to form a combustion, we have to burn more oil. Our fuel is oil, and we burn on an average four days, where the average was about seven days and a half before. The kilns used are 24 arches each, and where we used five men before we now use two. There are no ashes to haul away, no coal to unload. Our fuel is unloaded with a little steam pump, and it is then ready to be drawn by gravitation from the tank to the kiln. I can state unequivocally that I know of no inducement other than a pecuniary one, that would lead me to go back to burning common brick, artificially dried, with wood or coal. I'm not up on heat units, and shall endeavor to talk in a language that brickmakers can all understand. I don't know a unit of heat; wouldn't know a dozen if I should see them right

here. The cost of fuel has been, for oil, an average of 36½ cents per 1,000. Before we understood oil and its uses, we used a great deal more than we do now, and we are all the time improving upon it. Any science so new as the burning of brick with crude oil is susceptible of great changes, and I expect it to improve for the next ten years. The exact total cost of burning brick so far with me, I have been unable to ascertain, for this reason—I take my steam from a stack of three boilers, and the same steam from the three boilers is used for running my machines in the day-time and also for my kilns, and for burning brick; so I have been unable to divide the amount of steam used for burning brick, and the only way I can get at it is relatively, and my figures show the total cost for labor, fuel, oil, and coal for burning brick this year has been 53⅓ cents, as compared last year with 92 cents, when using wood and coal.

"If the cost of fuel was the same, if it cost me just as much for oil and wood to make steam as it did for wood and coal, I would still burn with oil. My arch brick, aside from the first 18 inches, are the best I have in the kiln. There isn't a check end brick or discolored brick, or anything that would damage them; they are really the best in the kiln.

"To use a burner with an aperture sufficiently small to make a light fire results in clogging that aperture with carbon. The hydro-carbon burner made in New York, and which Mr. Smith represented last year, is in many respects, I think, the most complete oil-burner I have ever seen. There were five apertures about the size of a knitting-needle in that burner.

"The first three kilns we burnt we had a good deal of difficulty in handling our fires with oil and getting the centres and outside corners and ends hot, and in throwing the heat to any part of the kiln desired; but now to get the heat we let one side go very light and fire the other heavily, so that the two flames, instead of meeting in the centre, face, just as in the old-fashioned way. I can get any heat I want inside of two minutes. We use slack coal on the outside courses. After start-

ing the fire, and the brick begin to sweat, which all brick will do, there is no difficulty in getting the fire up through them; and there is one advantage in the use of oil over the use of coal: in forcing your fire it is an absolute impossibility to choke your kiln with oil, and you have no ashes, no dust."

CHAPTER V.

CHAMBERS BRICK MACHINE.

AMONG the many efforts made to perform by machinery the various manipulations of brick-making, the inventions of Cyrus Chambers, Jr., of Philadelphia, Pa., stand conspicuous as successful machines for the purpose designed. Recognizing that a thoroughly tempered brick possesses certain essential qualifications not found when the tempering process was omitted, and that to produce the finer grades of face or front brick, known as "Pressed Brick," requires especial care in handling and forwarding, the Chambers Brothers Company, of Philadelphia, Pa., has devoted particular attention to the development and manufacture of machinery that stands pre-eminent for the production of superior quality of common building brick with the greatest economy.

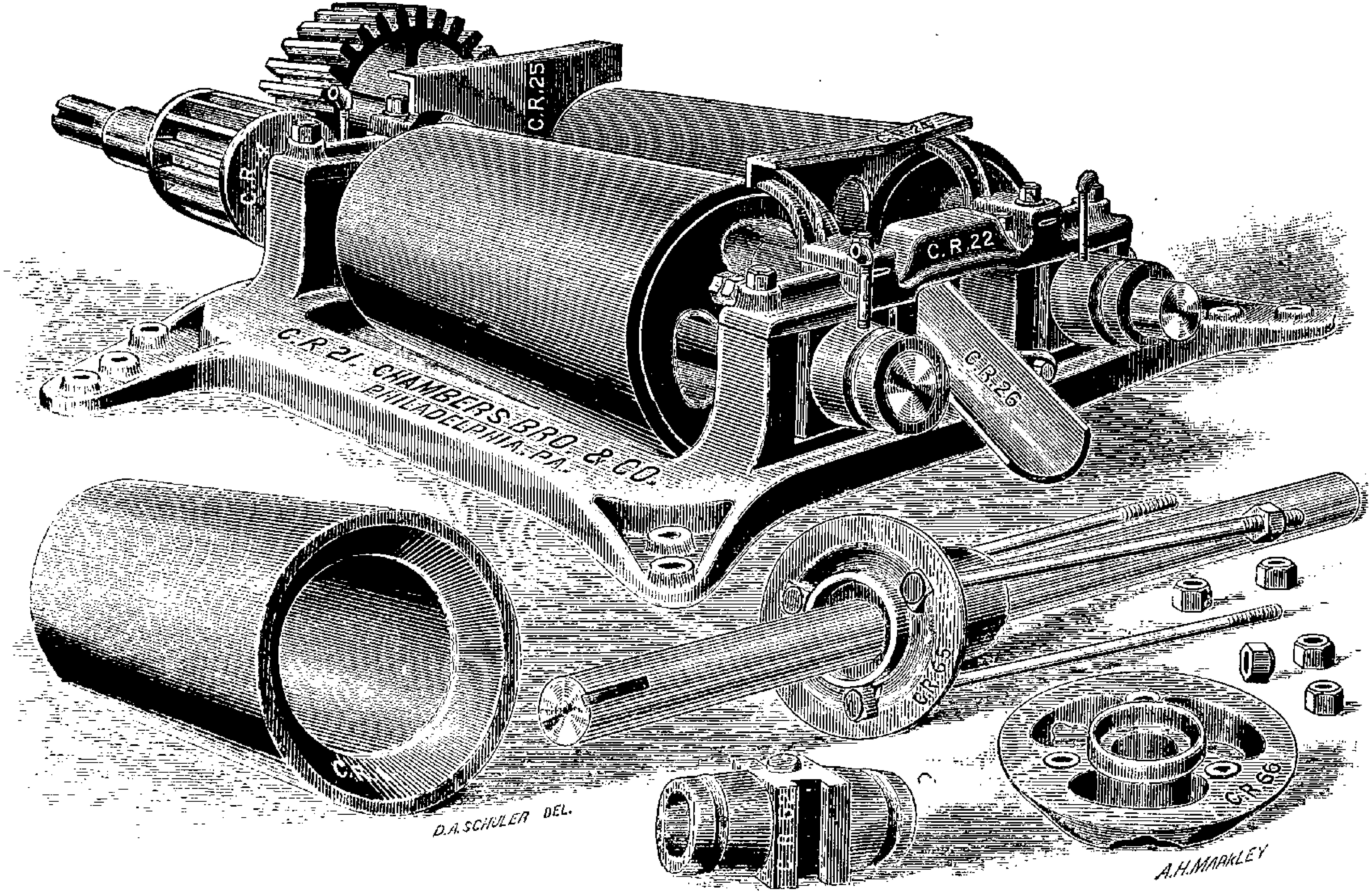
Mechanical skill of a high order is evidenced in the general design of the Chambers machine, and a thorough familiarity with the materials to be worked and their action on machinery is shown in the ready means provided for the cheap renewal of such parts as must of necessity in time wear.

When the clay to be worked is unusually strong, has limestone in it, or has hard, tough lumps that will not temper in an ordinary pug-mill or ring-pit, it is passed through rollers, or grinding mills, before being fed into the hopper of the brick machine.

The Chambers Single Conical Rolls, with detachable shells, illustrated in Fig. 60, serve to expel the larger stones, break up the lumps of clay, and help to mix the clay and sand together.

These rolls are cast in "Shells" or "Telescopes," so that the wearing parts can be renewed without replacing any of the other portions.

FIG. 60.



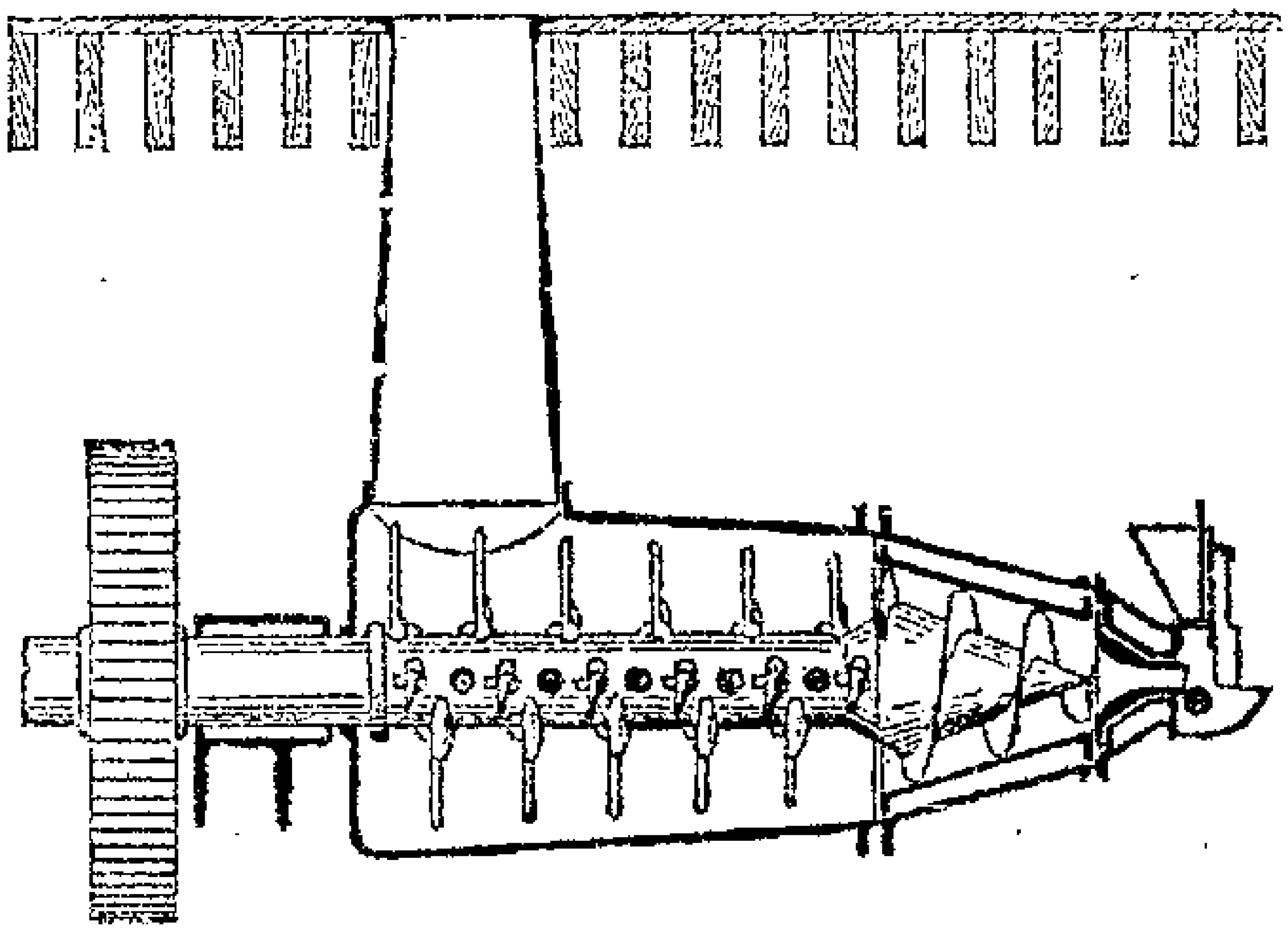
CHAMBERS SINGLE CONICAL ROLLS.

From beneath these rolls the clay is carried immediately to the hopper of the brick-machine. The Chambers machines mix and temper the clay with water as they use it, without additional handling. After tempering the clay they form it into parallel bars the desired width and thickness for a brick, sand the surface, cut the bar thus formed into uniform lengths, and then deliver the brick so moulded and sanded, at any convenient distance from the machines, sufficiently stiff to be immediately wheeled and hacked in the shed or on drying cars.

THE TEMPERING DEVICE.

The tempering portion of the machine (Fig. 61) consists of a strong cast-iron conical case, in which revolves a horizontal

FIG. 61.



shaft into which are set spirally, strong tempering knives, or blades of wrought iron or steel (see Fig. 62), so that, as they pass through the clay, they move it forward. The clay being stiff, and not having much water on it, is not liable to *slip* before the knives, but is cut through and through, and *thoroughly* tempered, the air escaping back through the untempered clay, so that by the time the clay reaches the small end of the tempering case it is ready to be formed into brick.

On the end of the tempering shaft is secured a conical screw of hard iron, which revolves in a hard iron conical case, the inside of which is ribbed or fluted lengthwise, so as to prevent

the clay revolving in it, and is hard, to prevent wearing (see Fig. 61).

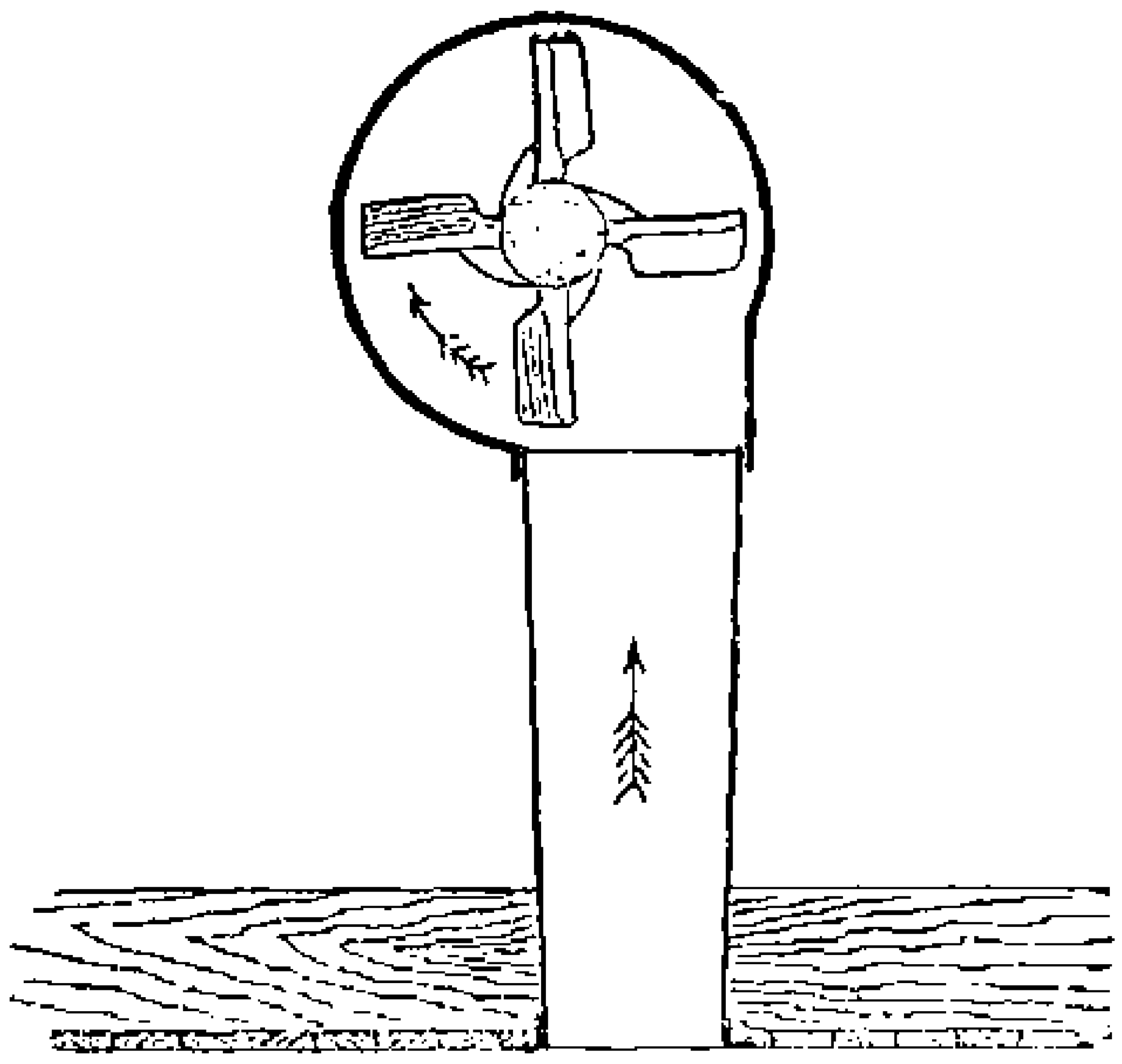
The screw being *smooth* and very hard, the clay slides on the screw, thus becoming, as it were, a *nut;* the screw revolving and not being allowed to move backward, the clay *must* go forward, sliding within the screw-case. This case is heated by steam, which facilitates the sliding of the clay and saves considerable power.

This operation further tempers the clay, and delivers it in a solid round column to the *forming-die.*

Plastic materials, moving under pressure, follow the laws of fluids.

The great difficulty heretofore experienced in machines ex-

FIG. 62.



pressing plastic materials has been to make the flowing mass move with uniform velocity through all its parts. As the channel of a river flows faster than the shallow portions, or those near the banks, so does clay move through a die, the friction of the corners holding them back, while the centre moves more freely. This difficulty is overcome by the peculiar form of the "former," which is so shaped as to facilitate the flow of the clay to the corners, and by this means the angles of the bar of clay are re-enforced and made very solid and sharp, thus insuring perfectly square and well-defined corners to the brick.

The "*former*" is secured to the screw-case by a hinge and swinging bolt, so that it may be quickly swung open for the removal of stones. This swinging bolt is secured to the case by a pin of just sufficient strength to hold under normal conditions, and when undue strain comes from hard clay, etc., it yields, thus forming a perfect safeguard against accidents arising from improper feeding. This "former" is also heated by steam, to facilitate the forming and sliding of the clay.

The forming and finishing part of the die (which determines the exact breadth and thickness of the bar of clay or the brick) is a hard iron lining, that can be removed and renewed in a few minutes and at trifling cost, thus enabling us to always keep our dies (or moulds), and consequently the brick, to standard size.

As the bar of clay issues from the forming-die, it passes through a small chamber filled with fine, dry sand, which adheres to the surface of the brick. The surplus sand is kept back in the chamber by swinging elastic scrapers, which allow the bar to escape with its adhering sand.

This sanded surface of the clay bar renders the brick, when green, much nicer to handle, prevents them from sticking together on the barrows or in the hacks, or on the *drying cars*, and much improves them in color when burnt.

This continuous rectangular bar is then cut into brick lengths by automatic devices which are under the control of the issuing clay bar. One of these devices is known as the spiral cut-off, and consists of a thin blade of tempered steel, secured to the periphery of a drum, in the form of a spiral, the distance between the blades of which is that required for the length of a brick, and the projection of which gradually increases from nothing at its first end to the full width of the widest brick to be cut.

This spiral knife runs perpendicularly in openings in the links of an endless chain, supported upon rollers, the chain being so formed as to support the bar of clay from the bottom and one edge; the clay is thus fully supported while being

slowly cut off by the long drawing cut of the spiral blades in passing through the openings in the chain.

The distance between the spiral blades being uniform, the lengths of the brick are absolutely uniform, and the drawing cut of the spiral blade cuts the end of the brick perfectly smooth, and almost mathematically square.

The speed of this spiral cutting-blade is controlled by the speed of the clay itself, hence, no matter how irregular the flow of clay from the die, the spiral runs in exact unison therewith, consequently the absolute uniformity in the length of the brick.

Fig. 63 shows the Chambers Machine as constructed up to and including the automatic sander.

Another device used by Chambers Brothers Company for severing the continuously moving clay bar into brick lengths is known as the "automatic wire cut-off," and is recommended by the manufacturers for smooth clays or those reasonably free from stones and gravel.

It consists of a regulating frame or table, on to which the clay bar is carried from the sander, and by which the cut-off is controlled or governed.

The belt carrying the clay bar runs around a measuring wheel, which determines the exact length the brick are to be cut.

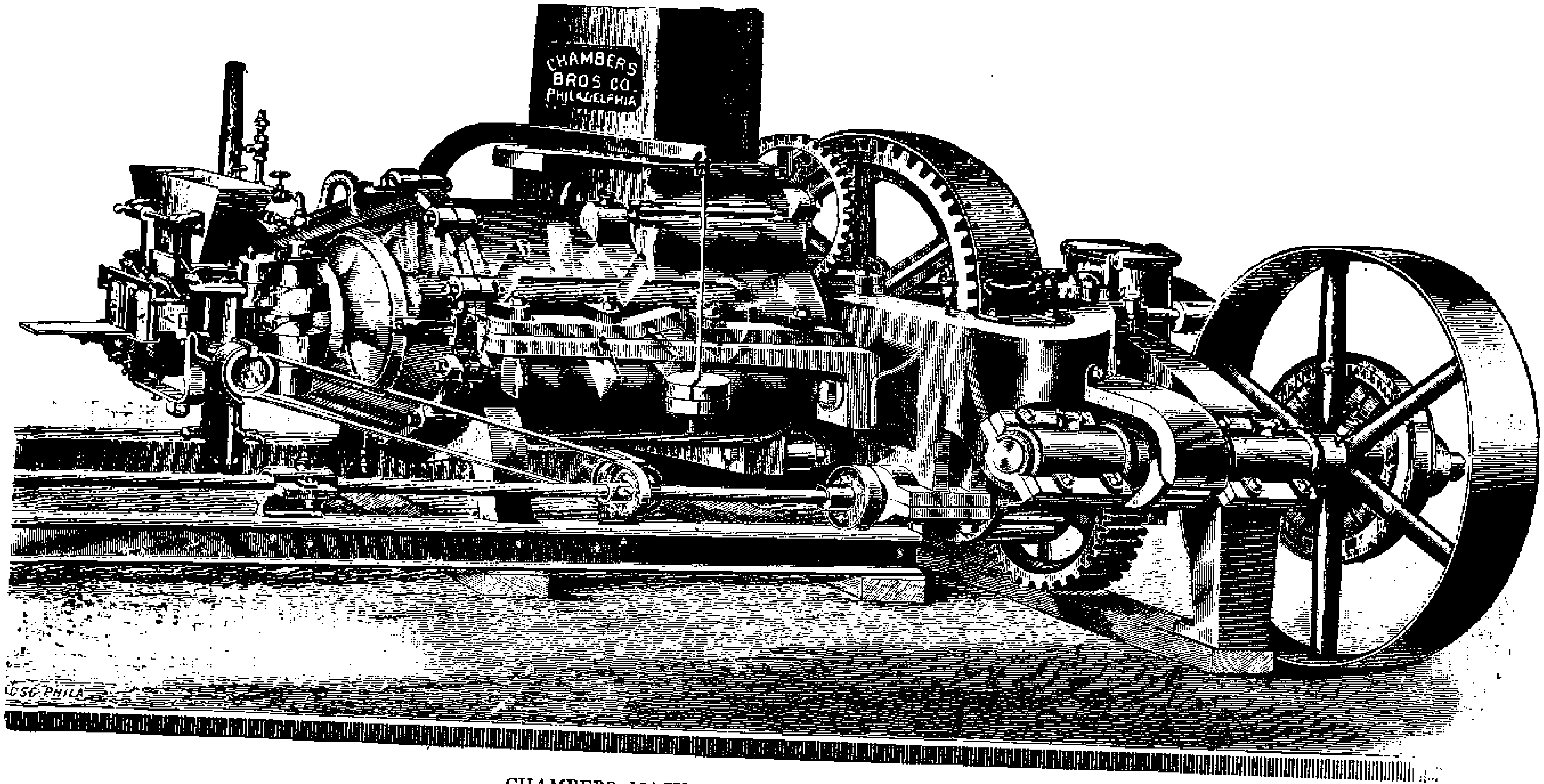
The cut-off wires are strained on steel bows or springs to the proper tension to cut, and yield readily to obstructions.

The wires are carried by their springs on a sprocket-wheel over and through the clay bar, and are guided square by a cam. encased in an oil-tight case.

The partly-severed brick is supported and held against the unsevered bar until completely severed, when it is dropped on to the off-bearing belt and promptly carried off, allowing the wire to return above the bar again between the brick and the end of the unsevered bar. Thus the bar is divided into uniform lengths with square heads and with all the smoothness that a fine steel wire will give in the clay.

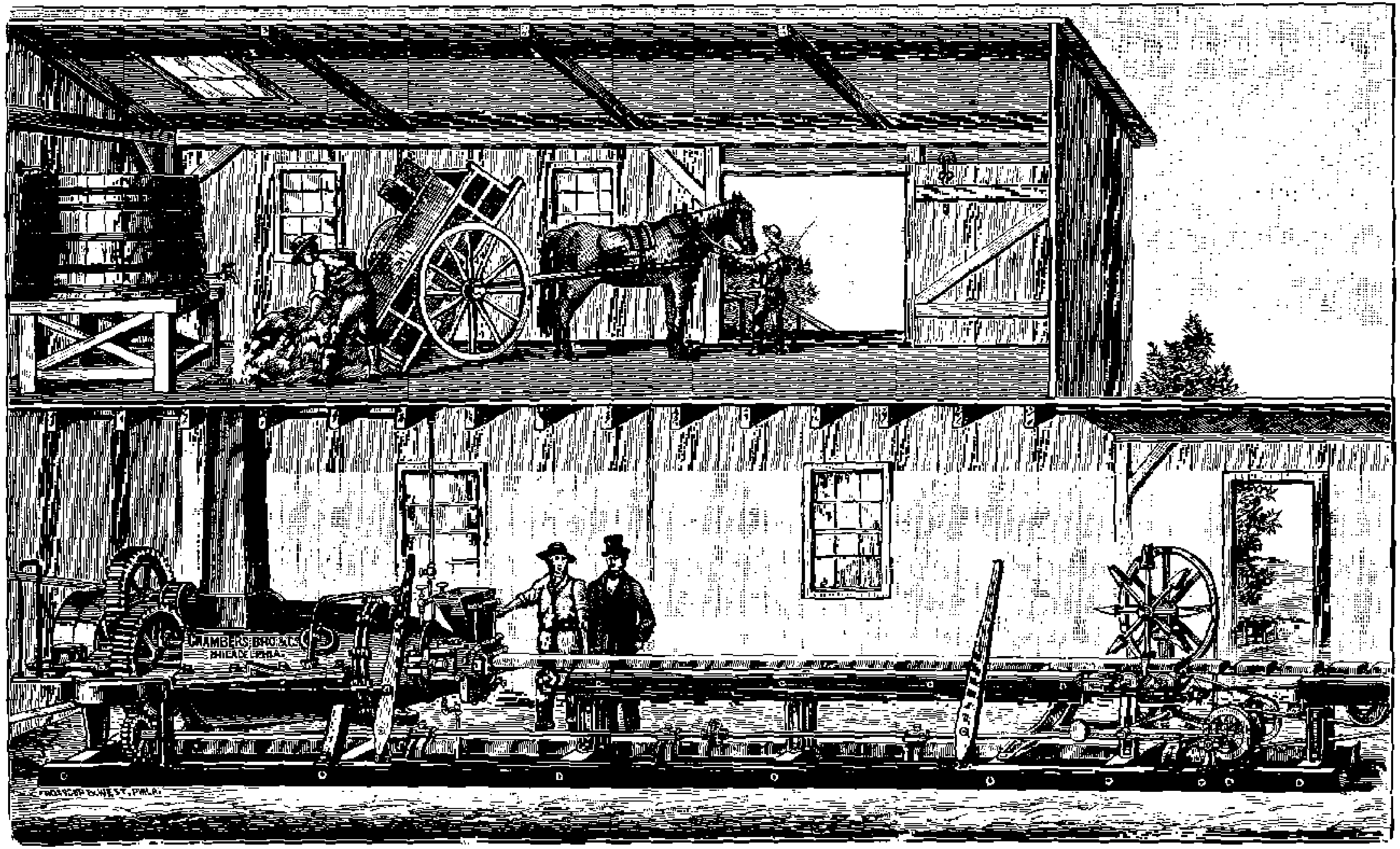
The wires either cut around the stones or spring over them,

FIG. 63.



CHAMBERS MACHINE WITH AUTOMATIC SANDER.

FIG. 64.



CHAMBERS MACHINE WITH AUTOMATIC WIRE CUT-OFF.

and run from morning until night without bother or trouble. Should a wire break, it can be removed at once without even stopping the machine.

Fig. 64 shows the Chambers machine as fitted with the automatic wire cut-off. Machines with this style of cut-off are made of different capacities, ranging from ten thousand brick per day to one hundred thousand brick per day of ten hours.

CHAPTER VI.

THE MANUFACTURE OF STREET-PAVING BRICK.

THERE are three things of prime importance upon which the successful manufacturer of vitrified brick for roadway paving depends. 1st. There must be a ready-made market at hand, with ample shipping facilities. 2d. The material to be used for the making of the brick must be suitable in its nature. 3d. The material must be sufficient in quantity to warrant the establishment of a plant of such a capacity as to meet the demand of the market.

These three things being present, they make it possible to obtain the capital with which to equip and operate the works, and skill in management and suitable labor are always commanded by capital. The purchase of special machinery for preparing the material and for moulding the same into brick form, and the erection of artificial dryers and kilns, are matters which depend wholly on the kind and nature of the clay, shale or other material to be worked.

The prime requisites for a good paving brick are:

1. That it shall have a vitreous body.

2. That it shall be of sufficient toughness to prevent crumbling under the traffic.

3. That it shall be free from pores, a dense mass which will not absorb the moisture, gases or impurities of the street or atmosphere.

To secure these, the first essential is selection of a suitable clay; the second, proper preparation; and the third, skillful burning, burning to the point of thorough vitrifaction, without risk of melting.

A description of the various clays suitable for the manufac-

ture of vitrified brick for roadway paving will be found described under the head of CLAY in Chapter II.

PAVING-BRICK PLANT CONSTRUCTION.

There is no fixed rule which can be followed in constructing paving-brick plants. Mr. Eudaly, who has had a large experience in this class of work, names the following general features which should be observed:

First: The dry pans or crushers should be so located with reference to the clay bank that the clay can be dumped to the crushers, in this way avoiding the great amount of manual labor that would otherwise be required to elevate the clay with shovels to the hopper of the crusher. Again, the clay should be dumped near enough to the crusher so that no conveying in wheelbarrows or otherwise is necessary. Of course this cannot be done when it is necessary to house a large quantity of clay for winter use. The crusher should be between the clay bank and the pug mill, if possible.

Second: The pug mills should be elevated above the machinery, so that one elevating the clay would carry it from the crusher to the machine.

Third: Need I mention so plain a matter as that of having the dryer and machine house in close proximity, and conveniently arranged, so that the brick from the machine can be easily and quickly put into the dryer?

Fourth: Or is it necessary to say that the dryer should be conveniently situated in reference to the kilns?

Fifth: Or that the kilns should be convenient to the railroad switch or road?

Yes, it is necessary, as I have seen during the past season several plants, and I regret to say some of them were new ones where these very simple, and to most men plain, necessities were sadly overlooked or disregarded.

Sixth: The railroad switch should be convenient to the kilns and the storage sheds. This is a matter often difficult to arrange, for the reas n that three unwieldy elements enter into

consideration—kilns, storage sheds and railroad cars. Both the storage sheds and cars should be convenient to the kilns and convenient to each other. These are requisites hard to accommodate, but as it is, no doubt, most economical to load the paving-brick directly from the kilns to the cars, the cars should have the preference over the storage sheds as to position. This being the case, many plants are arranged so that the bottom of the cars comes to a level with the kiln floor. This is done, of course, by lowering the railroad switch, which is very bad in winter or wet weather unless ample over-draining is provided. We know of a number of yards where the natural lay of the land is such that this arrangement can be had without excavating for the switch track. Now that the track is properly in front of the kilns, many locate the storage shed beyond the switch track, and by the use of strong rough boards wheel the brick across the track to the sheds. Once the brick are properly hacked under the sheds along the switch, they can be easily loaded into the cars. Of course, the floor of the storage sheds should be on a level with the kiln floor, and hence on a level with the bottom of the cars standing on the switch.

Seventh : The arrangement of dryer, kilns and cars or storage sheds should always be such, if possible, that the kilns may be emptied at the opposite end from that at which they are filled with the green brick, for the reason that it is very desirable not to have the brick setters and loaders in each other's way. If care is taken at this point, a great deal of annoyance and trouble will be avoided.

Eighth : The plant as a whole should be as compact as possible. I do not mean by this that the buildings should be small, for any one who has had experience knows that they should be large and roomy, but I mean that each and every department of the works should be as convenient as possible to every other part upon which it is directly dependent.

STARTING AND MANAGING A PLANT.

There are a large number of capitalists embarking in the manufacture of street-paving brick, men who make a success of their undertakings by surrounding themselves with the best experience and knowledge obtainable. On this point Mr. Wm. H. Brush, of Buffalo, N. Y., says:

"There is no business pursuit within the range of my limited experience or knowledge that calls more imperatively for a system than does the ancient and honorable calling of a brick-maker—a calling whose antiquity is beyond question, and of whose honor and respectability there is no need of defense. System bears the same relation to brick-making that a rudder does to a ship, and is as necessary. System is everything, from the clay bank of your yard to the first national bank of your native town. The old saying that 'Money makes the mare go' is true. We cannot in these days of 'spot cash' conduct a business without its aid. We must have some honest *bona fide* capital besides 'cheek,' and the more of the two combined the better, in order to make a success of brick-making. Capital without force or energy to drive things along is well nigh useless. Experience, with its many costly lessons, aids your understanding."

Mr. J. A. Reep says: "Above all things have a good, competent and reliable man as superintendent or other manager of your works, a man with practical experience and business tact, one who can command the respect of both employer and employés. Get him, and then make his situation so agreeable that it will pay him to stay and you to keep him. You will find enough men willing to serve in his stead, at lower wages; but it will be better for you, if he has got things to running smooth, and seems to have but little to do, to bear in mind that if you change for a new and untried man, with no qualifications for the place, that you and the new man both will be kept very busy for a long time to come.

"How often is it the case that after a few months of close management and well-directed effort on the part of the man-

ager, some member of the new company, who is a novice in brick-making in all its details, is constrained to believe that the superintendent is an unnecessary adjunct to a brickyard, and that they in particular have no need of a man of that kind! The hands they employ, apparently to them, do not need him, and can get along without him.

"The matter is talked over and worked up until, as a sort of trial to see how it will operate, the superintendent is dismissed, and his salary is saved. But at what cost to the company! The ruin of one kiln of brick, which always quickly follows, would have paid the salary for one or more years to come. And then comes not only one kiln lost, but several follow in quick succession, or partially so. Trade is lost that is hard to regain. Confidence is hard to restore in the ability of the company to furnish their advertised goods promptly and of a decided good quality, and for a time ruin is imminent."

THE SIZE OF PAVING-BRICK.

Mr. Shea, of Decatur, Ill., regarding the size of paving-brick, says: "There are about as many varieties in sizes as there are in clays. Different people make different sizes of paving-brick. The question is, which is the best size? I have come to the conclusion—and I think a majority of those who have made a study of the subject have come to the same conclusion—that the common building-brick size is not only the best size, but that it is the most profitable size to make paving-brick, and for the following reasons: First, it is very much easier to burn a small brick than a large one; next, I do not think there has been invented, as yet, a kiln that will burn all the brick exactly alike. At least I have never seen one, and I have had a great deal of experience with kilns. For that reason, there will be some waste in the best of kilns, and if you have the common building-brick size, you will see that the softer brick—those that are not hard enough for pavers—will sell very readily for building purposes. If you have a large lot of common brick it will be necessary to put your loss on them on the price of good

paving-brick, of course. Another point about the size: It is very much easier to repair a street, in case you have to make repairs, to allow for the putting down of pipes for gas or water, because you could take out a few brick and do the repairing easily and replace them. I think that would also be a good reason for adopting the common building-brick size for pavers."

There are several manufacturers of paving-brick who have discarded the idea of making such brick of building-brick size, preferring the "block" form. The majority of experienced manufacturers, however, agree with Mr. Shea, that the size of the "pavers" should be the size of the common building-brick sold in the local market where the street-paving brick are manufactured, as by adopting that size it is possible to burn them more uniformly, the loss will be less, the drying better done, and the cost of manufacturing less. A satisfactory roadway pavement must have a continuous surface. When the manufacturer cuts off the corners, he simply cuts off what it would require five years of traffic to accomplish on a vitrified brick street. So when completed you have a street five years old, and a rough street at that. The crude idea that some people have that the brick or paver must have a round corner, knobs, lugs and grooves in it, to keep the brick apart, so it can be filled with pitch, concrete or sand, in order to get the required alignment, is absurd, and is not at all practicable.

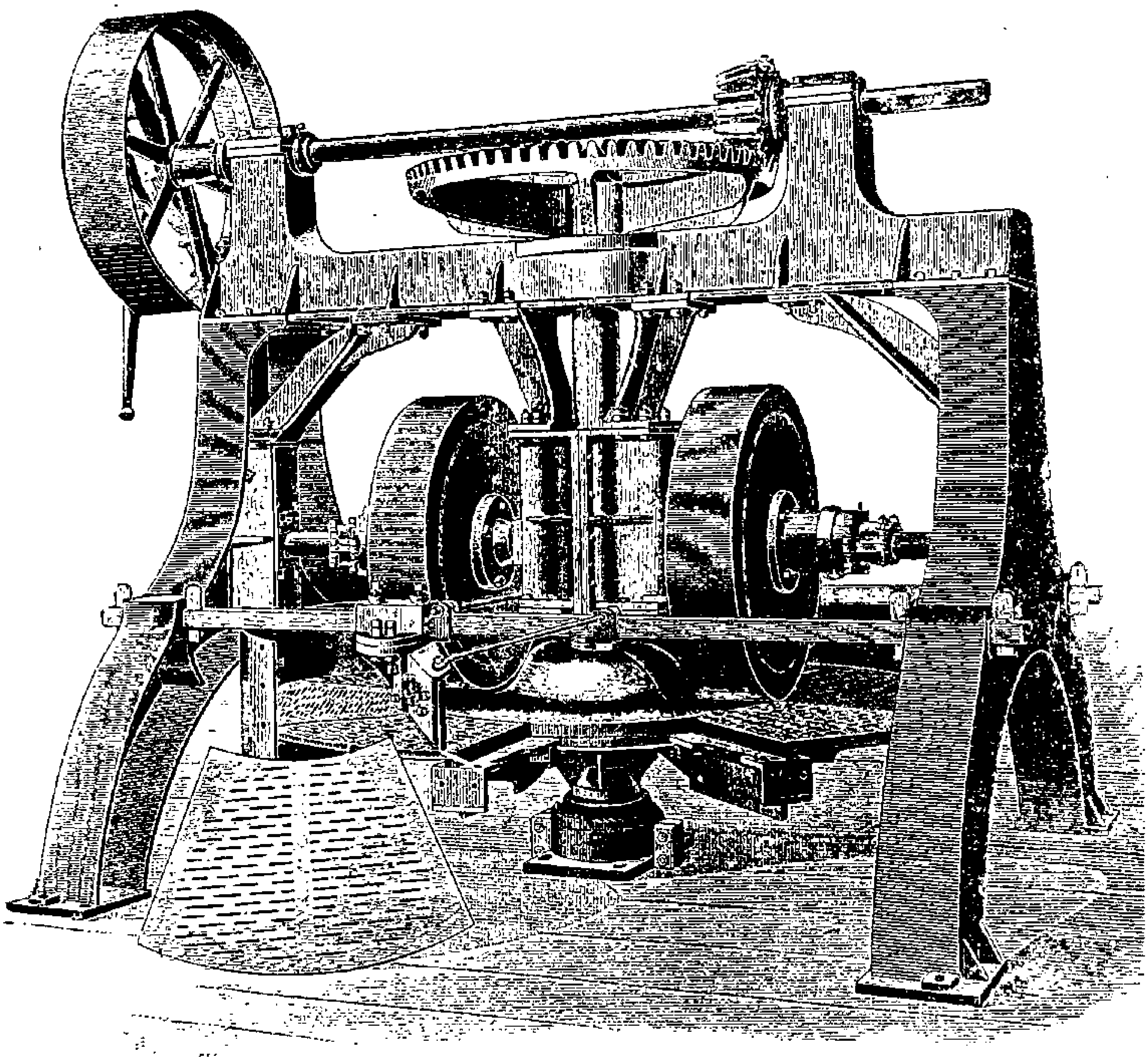
The waste brick that are not suitable for pavers, in the manufacturing of this kind of odd-shaped pavers, are thrown in the dump, as they are an odd size and shape, and can not be used to any advantage for other purposes.

CONVEYING AND GRINDING CLAY.

Shale clays are commonly mined by blasting, and the plastic clays by digging or "throwing" the face of the bank, which gives a good mixture, and after a sufficient quantity of the material is secured, it is automatically let down an inclined plane in dump cars, attached to a wire cable which winds around a grooved wheel. By this arrangement, the car laden

with clay, as it passes down the incline, pulls the empty car up to be refilled at the bank. When the dump car with its load of clay reaches the bottom of the incline, the material is automatically discharged from the car into a 9 foot dry pan, in which the material is thoroughly reduced and pulverized.

FIG. 65.



THE DRY-PAN.

Fig. 65 illustrates the dry-pan made by the Frey-Sheckler Co. This pan is built in three sizes, viz.: 7, 8 and 9 foot diameter. For strength and solidity it has no equal. It is designed for grinding fire clays, shale, quartz, cement, lime, flint, sand, spar, ochre, calcine, grog, plaster rock, plaster-paris, bones, coal, or any hard substances.

This pan has from 10 to 20 per cent. greater screening

capacity than any other pan of same size; it is also balanced so that a great speed can be obtained. It will readily be seen that additional centrifugal power is obtained to throw the material outward over the screening plates, and the screens are of such increased area that the reduction is increased in the same ratio.

These pans are built entirely of iron and steel. The vertical shaft has a hole through the center from top to bottom, through which the oil passes to lubricate the bottom bearing with unfailing regularity. The special arrangement of the bottom bearing, having an oil reservoir under and around it, revolving on the hardest chilled plates, with distributing oil grooves, saves friction, heating and wear.

Every joint is planed square, every hole is drilled, and each bolt is fitted with lock-nuts. Each roller has its own shaft, the ends of which are provided with blocks that move in guides in the frames, also in guides in the shrouds encircling the main shaft. The rollers move always square on the face of the bed, whereas if both rollers are on one shaft, if one is lifted, the other follows to some extent, so that only the corners touch the bed. One side of each vertical guide at the end of the roller is removable, which allows the shaft and roller to be taken out without delay. The ends of the roller shafts are supported by heavy coil springs, so that they are close to but do not touch the floor plates when the pans are empty.

The space between the rollers and floor plates can be nicely adjusted to suit each material by means of adjusting screws and rubber springs in the frames and shroud, which encircle the vertical shaft. The rollers have deep, hard chilled tires, which can be readily removed from centers when the substitution of new tires is necessary. The floor plates and screen plates are both chilled.

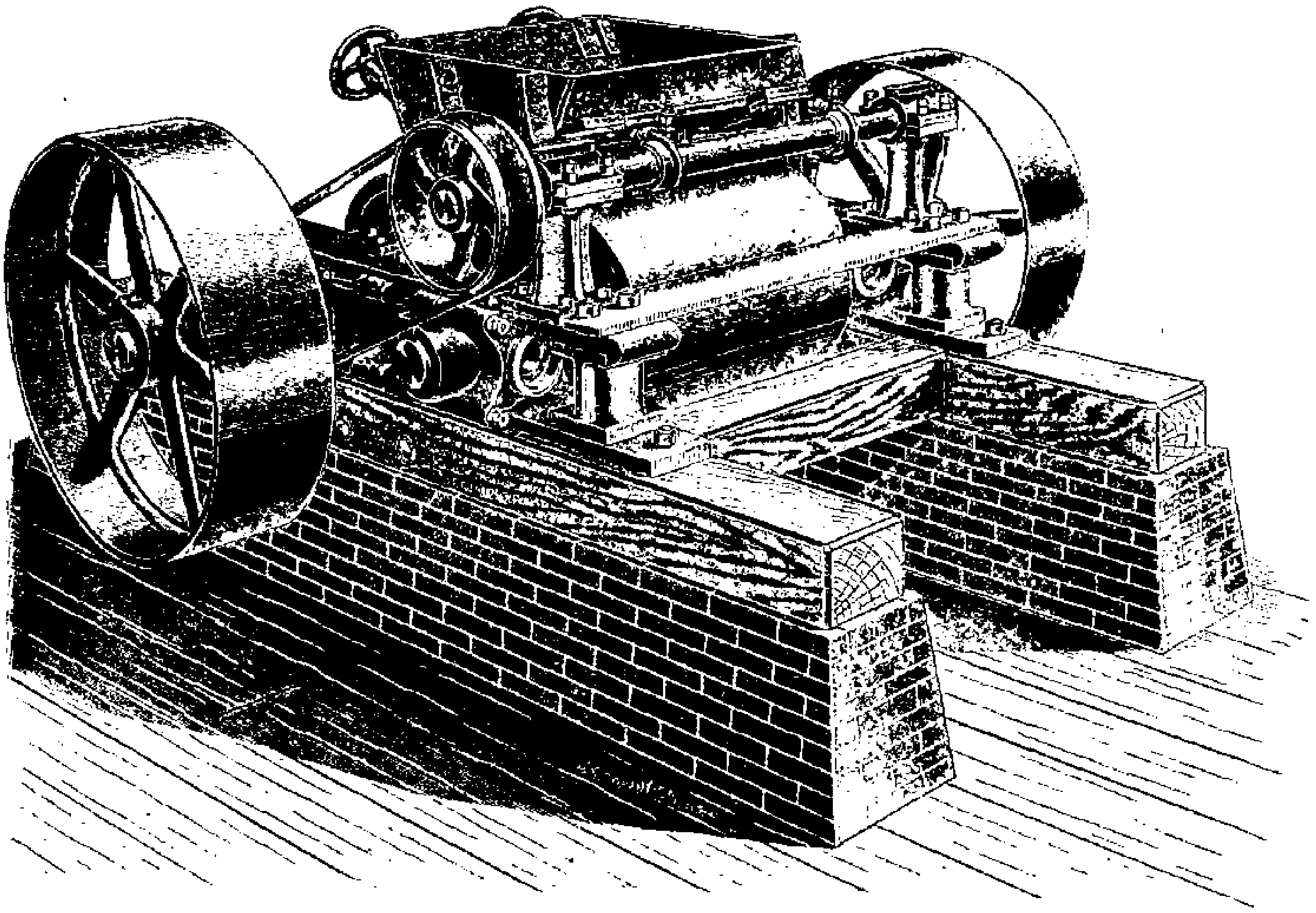
The scrapers are hung on universal joints, so that they can be adjusted in any direction; they are also provided with interchangeable chilled face plates, which render the wear of the scrapers four times as long as that of the ordinary scraper.

These dry-pans are driven with a friction clutch pulley 48

inches diameter, 12 inch face; speed, 150 revolutions per minute.

Approximate weight of 7-foot pan, 21,000 pounds.
Approximate weight of 8-foot pan, 26,000 pounds.
Approximate weight of 9-foot pan, 30,000 pounds.
This machine is fully protected by patents.

FIG. 66.



IMPROVED TAILINGS CRUSHER.

Fig. 66 illustrates the No. 12 Improved Tailings Crusher made by the Frey-Sheckler Co.

This machine is adapted for reducing the tailings of shale, fire-clays, or any refractory or silica clays. It is also adapted for crushing soft or alluvial clays.

The rolls, 20 inches in diameter, 26 inches long, are made of charcoal chilled iron, with steel shafts through them. The rolls are ground to a smooth bearing surface and are run at differential speed.

The clay is fed into the rolls by means of a vibrating apron, and the flow of clay is evenly regulated by adjusting screws. This machine is built very strong and rigid, and is a favorite

among brick manufacturers. The driving pulleys are 34 inches in diameter, 12 inch face; speed 175 and 250 revolutions per minute. Capacity, 30,000 to 50,000 brick per day, according to nature of the clay; weight, 4,765 pounds.

This machine is fully protected by patents.

From the dry-pan the ground clay is conveyed to the upper floor of the factory, where it is separated, the fine clay falling into a bin and the "tailings" or coarse clay passing by gravity back into the tailings crusher shown in Fig. 66 or into the dry-pan, to be again ground until it is reduced to such a degree of fineness as to allow it to pass through the screen into the bin.

There is not much room for economizing in the grinding and tempering of clay to be used in the manufacture of pavers, as the best grade of such brick can only be made from the material which has been properly ground and prepared.

Mr. G. H. Brown, of Sioux City, Iowa, says: "The first step in making a paving brick is the thorough preparation or "tempering" of the clay. *It must be ground fine.* I do not believe that a first-class paving brick can be made where there are lumps as big as peas scattered all through them. It may make a hard brick, good enough for sewers, and for similar purposes perhaps, but it won't be a paving brick. Our own clay is hard to manage—what is known as refractory clay. We run it through two dry pans and a pug-mill, but are dissatisfied with the texture even then. The clay is dug with a steam shovel, and consequently goes into the pans direct from the bank. It is damp, very tough, and inclined to be sticky and to pack under the 'ploughs' in the pans. The finest paving brick I ever saw in my life, bar none, are being made to-day at the Northwestern Sewer Pipe Works at Sioux City, where the clay, after going through a dry pan, is put through two wet pans, and that, to my mind, is a solution of the question—*provided* that sufficient capacity can be obtained by means of wet pans. That is a point which I am not competent to determine, but one that the makers of wet pans would do well to study, and perhaps improve upon."

MOULDING AND PRESSING.

On this point, Mr. G. H. Brown speaks as follows: "Having got your clay well 'tempered,' the next thing is to pass it through a machine which will *compress the utmost amount of clay into a given space.* Your bar of clay must be as dense, solid and hard as you dare to work your machinery. A soft bar of clay means a great shrinkage in the drying and burning, and an exaggerated change in the size of the brick in passing from the green to the dry state is sure to entail more or less checking and warping, and the result be a weak or distorted brick, to say nothing of the difficulty of handling, and a greater percentage of loss. Everybody knows there is a vast difference in the shrinkage of different clays; but in my judgment, when you are making a stiff-mud brick, make it stiff as you can, both by heaviest possible pressure in the machine, and by avoiding too lavish use of water."

If the clay is to be molded into brick by a stiff-clay brick machine, by which class of machines nearly all paving-brick are now produced, it passes by gravity from the clay-bin to the hopper of the brick machine, and is tempered and molded into brick, which are uniformly end-cut after the bar of clay reaches the cutting table.

Soft-clay brick machines are used in molding some clays, and side-cut stiff-clay brick machines are also sometimes employed.

If the clay is to be molded into brick by any of the ordinary forms of sewer-pipe machines, it passes from the clay-bin by gravity through a chute into a 7-foot wet, or tempering pan, where the different clays are thoroughly mixed and incorporated into a plastic mass by the addition of a sufficient quantity of water. After being thus made plastic, the tempered clay, on being discharged from the wet-pan, is again elevated into the second story of the building and discharged into an automatic feeder, which feeds the material into a sewer-pipe press. The brick come from the press usually in eight streams of suitable width and thickness for paving-brick, and are cut off into suitable lengths.

Paving blocks can be molded by either a stiff clay brick machine or a sewer pipe press. If the blocks are being molded on a pipe press, the clay passes through a die which allows only six streams to be emitted from the press, and these blocks are cut into 9 inch lengths, and it is common to make 20,000 of them in one day of ten hours.

It has not heretofore been usual to re-press paving brick made on stiff-clay brick machines. Some manufacturers of paving brick do, however, re-press them, and it pays to do so, as the brick by re-pressing acquire a greater density. The brick in this way become non-absorbent, and are of uniform size and finish. Such brick present a uniform surface for the passage of vehicles when the brick are laid in the roadway. The liability to flake or spall is also lessened by re-pressing.

The time has come when manufacturers of brick and blocks intended to be used for the paving of public roadways can no longer afford to put such brick upon the market without re-pressing them. The only reason why paving brick and blocks have not, in all cases, been re-pressed in the past, is the fact that manufacturers of this class of clay wares have been so crowded with orders that they have been enabled to put upon the market large quantities of brick and blocks which ought never to have left the yards where they were made. The rapid extension which is now going on in both the construction of new plants devoted to the manufacture of street paving brick and in the enlargement of the capacities of such plants already in operation, make, in a great measure, the shipment of inferior paving brick anc blocks in the future almost impossible—the reason of this being that there is now a more general and thorough knowledge concerning the qualities which are necessary to be possessed by vitrified brick and blocks, if they are to be used for the paving of roadways. A paving brick, if it is properly made, should be so dense as to make it impossible for such a brick to absorb even an ounce of moisture. Such a brick must, in addition to great density, be true in shape, having good corners, heads, faces and arrises in order that the

brick, when laid in the roadways, shall lie close to the neighboring brick and present a smooth, uniform surface. There is no possible way by which these desirable qualities can be imparted to a paving brick, except by re-pressing.

Paving brick, with of course fusible toughening elements, are properly prepared for the greatest constructive element, fire, by pressure; hence, as a sequence, their absorbent conditions are practically wiped out.

Common building brick generally, on account of their uses, are not subjected to great pressure; hence absorption rules at from ten to seventeen per cent.

What gold and silver are to commerce and the arts, what chemistry is to life; what order is to nature, so is pressure to all paving brick products.

The Chicago Roadway Paving Ordinance, which was recently passed, provides that all brick used for paving purposes in that city "shall be of the kind known as re-pressed brick, and shall be re-pressed to the extent that the maximum amount of material is forced into them."

DRYING.

The brick after being molded by the stiff-clay brick machine or pipe press, or which have been re-pressed in the manner described, are loaded on trucks and carried to the drying tunnels. Of course brick intended for use in street-paving can be dried in any of the ways in which brick made by the stiff-clay process are commonly dried. In the best forms of artificial dryers the brick dry without cracking, and are in as good a condition for setting into the kiln as it is possible to get them even if they were dried in the open air. The advantages of artificial drying are many and are well-known: the cost of building and maintaining sheds is saved; the loss from rain or floods when the brick are dried in sheds is also saved; rainy and freezing weather do not cause interruptions and loss of time; the works can be operated continuously throughout the year; time and fuel are saved in water-smoking, which is the

same as increasing kiln capacity, and there are no delays in waiting for dry brick. Most paving brick clays can be dried in twenty-four hours; some clays are so tender, however, that a longer drying and hence a greater drying capacity are necessary than with the strong, rapid-drying clays.

BURNING.

After the brick have been exposed to the action of the heat for a sufficient length of time in the drying departments of the factory they are conveyed to the kilns on the cars on which they are dried, or are wheeled and set for burning in down-draft kilns. The "water-smoking" or steaming of the brick requires about three days, after which the temperature of the kiln is gradually raised for 24 hours, and then for 48 hours additional the brick are given heavy and full fires in order to thoroughly vitrify the material. The cooling of the kiln is done slowly, the draft being checked after the final fires. The brick are drawn from the kiln by loading them upon wheelbarrows, on which they are usually run over a gangway directly into the cars which are to convey them to some other city or town. The switch from the main track of the railroad should allow the cars to approach close to the burning kilns, which should, if possible, be so built that the kiln floors are on a level with the top of the cars.

The use of crude oil for the burning of vitrified brick is a great advance over the employment of coal. Crude oil is more economical in many locations than coal, and more intense and steadier heats can be had with oil than with coal, and the vitrification of the clay is more thorough with oil than with coal; hence a better and more satisfactory product is secured. Fuel gas is, however, the coming fuel for burning not only street paving-brick, but all other forms of brick made from refractory or semi-refractory clays. As a rule, street paving-brick require to be fired from twenty-four to thirty-six hours longer at the highest heat attainable in ordinary down-draft kilns, than do hard building-brick made from the same clay. The brick for

street paving purposes must be slowly cooled, so as to anneal them and impart the desired toughness, without which the brick are not salable.

The question is often asked: "All things being equal, what is the difference in the cost of burning paving-brick and the common hard building-brick?"

Mr. E. M. Pike, of Chenoa, Ill., has answered this question as follows;

"With our clay fired up to the point which we denominate good hard brick (there is a chance of variation as to what a hard brick is), brick that would do for sidewalk, or the face of a building, or for side walls—we hold this same brick about twenty-four hours after passing from this time. With our clay the brick will vitrify; with other clay you might hold the brick for forty-eight hours and they would not vitrify. The question is, what is the difference in the cost of burning paving-brick and common hard building-brick? I would say that the difference in cost is the cost of the fuel it takes to run that clay from the point necessary to burn building-brick to the point of vitrification, adding the cost of the men it takes to fire the whole kiln from the hard building-brick point. That would be our expense.

"We finish the kiln of the common hard building-brick at the point of white heat, a heat that resembles the electric light. We continue the fires and continue that heat right along. That white heat is as hot as we can make it. We continue that heat for about twenty hours, and at the end of that time our brick are vitrified."

In giving the result of his experience regarding the manner of burning street paving-brick, Mr. A. O. Jones, of Zanesville, Ohio, says:

"The best results in burning, so far as my knowledge goes, are from that class of kilns known as the 'down-draft,' for with these kilns you can retain the heat and allow your brick to anneal and toughen."

In Atchison, Kan., down-draft kilns are used for burning

street paving-brick, and this form of kiln is largely used by paving-brick manufacturers.

At Sioux City, Iowa, and at Beatrice, Neb., continuous kilns are used for the burning of paving-brick.

Mr. H. Dawson, Sr., of Springfield, Ill., in speaking of the burning of these brick says:

"In the first place it is quite necessary to have the right kind of a kiln to burn with; for a vitrified brick the kiln should not be too high nor too wide, and I do not think you can burn successfully with an up or down draft kiln alone. It is necessary to have up and down draft combined to get from eighty to ninety-five per cent. of good hard top brick. I do not think it advisable to set them more than thirty brick high, as too much weight is apt to press them out of shape. We know that clays vary a great deal, but I claim that lots of time be taken in water-smoking, and then heat up slowly till you get it to the right pitch and then keep it there. When the kiln has begun to settle, it is very necessary that it should not be allowed to stop. For the first two days we do not let it settle more than one inch in every twelve hours; after that the kiln is well heated through and settles faster; we call fifteen inches a good settle for our clay. After you find your kiln has a good settle and you think there isn't a soft brick in it, burn it twenty-four hours longer. Of course I do not mean that exactly, but you can do more harm by closing a kiln too soon than by burning it too long. I am a brick man, and expect to make my living at that business as long as I live, and the more brick I sell the better I like it; but I do not want anything put into our streets and roads other than a good, tough, well vitrified brick, that will last from fifty to one hundred years on an ordinary travelled road, without any repairing."

Mr. G. H. Brown, of Sioux City, Iowa, on the subject of burning paving brick says:

"We now come to the final stage, viz., the burning; said to be the most important of all the various steps in making a paving brick. For my part I think one step is just as important

as another. You may get a first-class burn on a poorly made brick out of poor material, and yet you won't have a paving brick. The burning, I think, is probably the most difficult part of the business, but with proper care and experience there is no need of throwing away money and time on bad burns, although the first requisite towards a good burn is a well built down-draft kiln. My advice to one about to build a kiln for burning paving brick would be: 1. Build a down-draft kiln. 2. Don't be afraid of spending an extra dollar or so in buying fire-brick for lining; they will pay big dividends. 3. Clamp your kiln in the very best manner; if you produce a bona-fide paving brick, your kiln will need strong bracing. 4. Put a double crown on your kiln, two courses of brick, lower course 8 inches, upper course 4 inches.

Mr. W. E. Eudaly, of Cincinnati, Ohio, says: "A paving brick should be burned thoroughly hard and to that condition where it will be as tough as it is possible to make it, and it should not be burned beyond that point. Now you may call that vitrification, but that is the condition in which we want it, a condition in which it will stand the greatest number of blows; a brick burned until it will stand the greatest number of blows. It is not a question of crushing; it is a question of blows and absorption; and you will find the journals throughout the United States which are giving this question a great deal of attention have come down, many of them, to these two tests, of the question of blows, of the strikes they will stand, and the amount of water the brick will absorb, and those are vital questions in paving brick."

In speaking of the subject of burning paving brick, Mr. D. W. Stookey says:

"Down-draft kilns seem to be best adapted to burning this class of clay goods, as well as many others. Two points of advantage of down-draft kilns are of so much importance that they generally hold the position of first place in the minds of the manufacturers of the heavier classes of clay goods. One of these advantages is the uniformity with which the heat may

be distributed throughout the kiln, and the other is, because the ware that is heated most and that may become soft from the heat and liable to change its form under pressure is upon the top of the kiln and is subjected to but little pressure.

"In up-draft kilns the parts that are hottest are in the bottom and must sustain the weight of all above when the kiln is heated to the degree necessary to fuse the particles together and vitrify all that is vitrifiable. The pressure to which the lower brick are subjected by the superimposed brick will very likely cause many of them to stick or weld firmly together, and many will be badly distorted.

"To the manufacturer of paving brick the subject of fuel for burning the kilns is one of interest, and to which much thought and speculation are given. Of the four kinds of fuel in use, wood, coal, oil and gas, it may be said that any of them will produce the necessary heat. The function of a fuel is to generate heat, and it probably matters but little in the end whether the brick have been burned by heat produced from one or another. Heat is heat, and nothing else, whether it is generated in one way or another; whether by mechanical, physical or chemical agencies.

"Since the draft is from the furnaces through the ware in the kiln, and the gaseous products of combustion, with all else carried by the draft pass in contact with the ware to be burned, it is probable that the color of the burned goods will be somewhat affected by the particular fuel used. The principles involved in producing a salt glaze teach that chemical action may take place upon the outside of the ware by the influence of some of the substances carried into the kiln by the draft; but this action is so slightly different for different fuels that it need not be considered by the manufacturer of paving brick.

"There are local influences that bear upon the circumstances of each particular manufacturer, and these must be taken into consideration in the selection of fuel suited to each case. It is common to see in print arguments and testimonials based upon

experience in favor of this or that kind of fuel, and these are often valuable and worthy of consideration in the comparison of different fuels; but, as stated above, each one must select that kind best adapted to his peculiar circumstances. This stated in another way means that each one must select that fuel with which he can burn his kilns with the least expense.

"It may be true that some are more easily handled than others, or that they will sustain a uniform heat with less attention; that they are more cleanly; they may have this or that argument in their favor; but the one idea to be constantly kept in mind is, which one will burn a given amount of brick satisfactorily with the least expense. Brick manufactories are operated as money-making establishments, and the money made is the difference between the expense and the income. The manager who adopts this or that kind of fuel for burning his kilns because it is the latest 'fad,' because it is more cleanly or more convenient, when he could burn his brick satisfactorily with less expense by using some other kind of fuel, has lost sight of the object sought in the establishing and operation of the plant. If the kilns can be burned with coal-slack or cord-wood for less money than with natural gas, the burner must be denied the luxury and covenience of using gas.

"In considering the expense of burning, the cost of the necessary outfit must be taken into consideration. With cord-wood, the outfit may consist of a pair of leather mittens and a long fire-hoe, costing, all told, a dollar and a half.

"With coal, the necessary apparatus may be a few rough boards, a shovel, an iron poker, with a wheel-barrow added in some cases. With natural gas, a system of pipes and 'appurtenances thereto,' are required, and in order to burn crude oil successfully, an elaborate outfit, consisting of tanks, pipes, pumps and burners, to which, in some instances, must be added a steam generating outfit, and in others, the steam generator with an engine and air-compressing attachment.

"Experiment may have demonstrated that a certain number of gallons of oil are equal to a ton of coal in producing heat,

and that the cost of the oil is something less than that of the coal, and yet the argument may be in favor of the coal, because of the necessary expense of the outfit to be used, in order that the oil may be burned successfully.

"It must be borne in mind that this matter will depend, in a great measure, upon the amount of fuel to be used by the plant. If the difference in the first cost is only slightly in favor of the oil, it would not be profitable for a plant of small capacity to abandon the use of coal and substitute oil; but if the consumption is large it may be that the small difference in cost will, in the end, amount to more than the extra expense of the outfit for burning oil.

"The idea of producing the most goods for the least money should be constantly kept in mind, and that fuel should be used which will burn the kilns and produce satisfactory brick for the least money. Just so soon as the manager of a manufactory begins to introduce plans and systems because of their convenience, style, or appearance, while they incur additional expense over others that produce as good goods, just so soon he ceases to obtain the best results and the greatest possible dividends for the stockholders or profits for the individual proprietor, as the case may be.

ANNEALING.

"Toughness is one of the essential characteristics of a good paving brick. It rests very largely with the burner whether or not the brick from his kilns are tough or brittle. True, the proper kind of clay must be used, for it is not to be asked of the burner that he will produce good tough brick unless the brick given him to be burned are made of clay selected because it contained the elements necessary to make the required brick if it be properly handled. Yet so much does proper management of the kiln influence the toughness of the brick that the success of the enterprise rests upon the skill of the burner in annealing the brick, and thus giving them the necessary toughness. The best of clay may be selected, the most improved machinery employed, the best methods of management

adopted, the brick may be carefully dried and go into the kiln without a crack or check, and yet improper management of the kiln at the time of closing may make the brick rotten, dead, shaky, checked, cracked, and wholly unfit for the purpose for which they were intended.

"When the kiln has been properly burned and the burner pronounces it finished, the process of annealing begins.

"The one principle involved or end to be attained is slow cooling.

"Every observing burner has noticed that pieces taken from the kiln while red hot and cooled rapidly in the air or in water present a cracked and crystallized appearance upon being fractured, and that they are easily broken and are devoid of the metallic ring that is so desirable. Annealing is a process that is arranged for by the last acts of the burner before leaving the kiln. It is in no way performed during the firing of the kiln, the raising of the heat nor the holding of the temperature while the heat is being driven through the kiln, but is strictly an act of cooling.

"It is well known that the particles of a body change their positions somewhat during the expansion attendant upon heating. If the body is slowly cooled the particles may return to their former position of stability, but if cooled rapidly, they are arrested in the positions that are more or less strained.

"There is a constant tendency while in this strained state to change position, just as a strained spring or bow tries to return o its original position. A blow or shock tends to shatter the iece by breaking the tie at some point and thus destroying he equilibrium. Glass manufacturers recognize this, and by nnealing, which consists in re-heating and cooling slowly, llow the particles to assume positions less strained and more table, and consequently the glass is more tough and not so asily broken.

"This strained state of the particles of a body that has been apidly cooled and the brittleness attending may be made learer to the mind by considering the conditions that exist in

a bow that is bent or a spring that is strained. When the strain is carried to the limit, it is observed that just before breaking the spring or bow reaches a hard, stiff condition and seems to stop bending, and, as it were, tries to resist further flexure, as if it knew that to go farther would be fatal.

"Now, this is the condition of the particles of the brittle body that has been cooled rapidly. If the cooling process has been too sudden, the body cracks, as seen in the tile or brick that has been taken from the fire and cooled quickly in the air or in water. When the bow has reached the limit, it is in a condition that it may be broken by forcing it a little farther, it is in a brittle state. Whereas, if it is not bent at all, but is in its normal position, it may be said to be tough, and may be bent considerably in any direction without breaking. In cooling an object slowly, the particles are allowed to assume their normal positions and are at ease, and the object may be said to be tough. If cooled rapidly, the particles are arrested in a strained condition, and it may break if forced a little farther, that is, it is brittle."

METHODS EMPLOYED BY VARIOUS MANUFACTURERS OF PAVING BRICK.

Mr. Beattie says: "The brick that we are making in Atchison, Kansas, is made out of a blue-colored shale that is very hard. We have to use dynamite to blast it. The manner in which we became engaged in that industry I can say was by the Galesburg people, four or five years ago, sending some brick out to Atchison to pave a street. Some of us who had seen the brick became interested in the industry, and took our clays and had them tested, which tests proving satisfactory, we entered into the manufacture of brick. But to continue, as to the manner in which we are making the brick, we use a dry-pan, and have a pug-mill and stiff-clay machine.

"So far as my experience goes, the best paving brick I have seen is made by the stiff-clay process. I am not interested in any machines or anything of that kind; I do not care the snap of my finger for any of them; but close to where I live there was

an effort made to try to make street paving brick by the dry-clay process that was a dismal failure; out of the same material good brick are now made by the stiff-clay method of manufacture. There may be clays that will make brick by the dry method, and which will do for paving, but for my part I have not seen them yet.

"I would not make the corners of paving brick entirely square, but a very little round at the edge, not so much as most men making brick give it. Where there is too much of a round there is a chance for the wheels of passing vehicles to grind continually on the edges of the brick."

Mr. A. O. Jones, of Zanesville, O., says: "As to my ideal mode of making the best paving brick I shall refrain from the attempt to mention, but among the methods of manufacture in use in Ohio is that employed in preparing the clay for the manufacturing of sewer pipes. After the clot or glut brick is formed it is then re-pressed, for unquestionably this densifies the body. Re-pressing takes a little more fuel for burning, but it adds greatly to the lasting qualities of the brick. It also gives it a finished look. Good workmanship, and then add to this perfect burning, for this is of the most vital importance, and the result is a good paver."

The Grape Creek Clay Company, of Grape Creek, Ill., uses a shale clay which, when freshly mined, resembles rock. It is first subjected to heavy crushers, put through enormous rollers, ground dry, and elevated to a revolving pan, when two massive rollers running in opposite directions grind the shale to an impalpable powder, and subject it to a sifting process. It is again ground in a gang mill, made into the shape desired. (They make three sizes of blocks—4x4x12 inches, 4x5x12 inches, 4x6x12 inches.) The blocks, after being molded, are partially dried, then subjected to an intense pressure, then placed on racks to dry. In burning, the heat is raised gradually and cooled off slowly, by which means the material becomes thoroughly annealed, and the result is a brick tougher than granite.

Messrs. Stewart & Collins, of Hastings, Neb., take a rough

clay from the bank and run it through a disintegrator and pug-mill, which reduces it to dust, and pug it to a stiff mud, issuing it through the die of a stiff-clay brick machine, which automatically delivers the brick upon the pallet hard, smooth and straight cut, at the rate of from 35,000 to 40,000 per day of ten hours.

Their clay bank stands thirty feet deep, and is above the track where it is loaded, being a solid mass consisting of an equal mixture of iron, shale and fire-clay. The brick made is of standard size, and when burned weighs six pounds. They use the portable hack, the track system exclusively. The clay will dry in sun or wind. They have had no cracked brick whatever, and use a common up-draft kiln, with coal for fuel, set thirty-four long and thirty-eight high. They burn from ten to twelve days, and use considerable clay on kilns, as the heat shows on top. They fire from both heads at all times, with partitions in centre of each arch, and have no trouble to keep a uniform heat. The firm are satisfied that there are more economical ways of burning, and will introduce them in their plant.

The Evansville Pressed Brick Co., of Evansville, Ind., use a mixture of clays for producing vitrified street paving brick. Fire-clay, obtained from Lincoln, is mixed with clay obtained from their own yards. The clay is first thrown into a dry pan, where it is crushed by two large rollers, weighing three tons each. It is ground down into a powder. It is then carried by means of a belt, with buckets attached, to the pug-mill, where it is moistened and thoroughly ground and mixed. From the pug-mill it passes into the top of the stiff-clay machine. Here the process of mixing is concluded and the clay is ready for the moulds. By suitable mechanism it is moulded under a pressure of 50,000 pounds to the brick. This makes it an impossibility for defects to occur within the finished product. The moulded brick then passes out on a belt; it is cut and placed on a car. When 500 are obtained the car is pushed down a track to the dry-house. In this the car remains for a period of about thirty-six hours. Steam is used in the dry-

house and temperature gradually increases. After leaving the dry-house, the product stands until it is ready to be placed in the kilns for burning.

The burning is done in down-draft kilns, the fires being held at finishing about twenty-four hours longer than for building brick.

The Purington Paving Brick Co., of Galesburg, Ill., use a shale clay, which during the last few years has become famous as the material from which the celebrated Galesburg paving brick are made. The shale is reduced to powder by being subjected to the action of two large size dry-pans, and after being rendered plastic by mixing with water, is formed into brick shape by two stiff-clay brick machines. From the machines the brick pass on cars into a steam dryer. Sixteen Eudaly down-draft kilns are used in which to thoroughly burn and vitrify the brick. These kilns are eighty-three by eighteen feet inside measurement. Crude oil is used for fuel in these works, and it has been demonstrated to be far superior to wood or coal, and the quality of product seems to be better and the vitrification more thorough and complete.

From one-fourth to one-third more time is consumed in burning than with the ordinary building brick. In burning, the brick shrinks from nine inches in length to eight inches, and proportionately in other directions. It is thoroughly vitrified throughout, and weighs five pounds. This brick will resist the best steel drill, and a chip will scratch glass.

A peculiarity about this plant is that no tight and loose pulleys are employed, clutches being used altogether.

The buildings are all of brick, being heated by steam, and it is intended to run winter and summer continuously. A coil of pipe is extended under the dry-pans, so as to prevent clay from freezing.

The Ottumwa Paving Brick and Construction Co., of Ottumwa, Iowa, use a mixture of strong clay and shale. The cars when loaded are drawn up into the clay house and dumped. Here workmen shovel the clay and shale into a dry-pan. After

being pulverized as fine as powder the material is hoisted by means of an elevator to the pug-mill on the second floor, where water is added and the material tempered. The material next passes by gravity to the brick machine, immediately below, where the brick is rapidly shaped by a stiff-clay brick machine. As fast as the brick are made they are loaded on cars and run into the artificial dryer, where they remain twenty-four hours. They are then taken from the dryer and placed in the kiln to be burned, this occupying some ten days.

The capacity of the plant is 50,000 brick per day and more than that number is frequently made. The six down-draft kilns have each a capacity of 250,000 brick.

The buildings at present occupied by the plant are a clay house, 30x100, a machine room, 30x70, and an artificial dryer, 30x140 feet.

CHAPTER VII.

THE MANUFACTURE OF DRY-CLAY BRICK.

THE term dry-clay as applied to the manufacture of brick is to a certain extent a misnomer; it would be more truthful to say semi-dry-clay brick, for the clay for the manufacture of brick by the dry-clay system is gathered with a view to obtaining it as dry as possible, usually by plowing shallow, allowing the clay to dry in the sun, and then gathering it and storing it in sheds. There is, however, even after the greatest expenditure of care, a sufficient quantity of dampness developed after passing the clay through the crushers and the pulverizers to enable one to press it into a ball by the pressure of the hand, which could not be done if the clay was perfectly dry, in which condition no amount of pressure developed by modern machinery would press it into a perfect and solid brick if the clay were entirely dry and free from water. Brick of this character are not a mud or tempered-clay brick; therefore, for the purpose of the present description, we will call it a dry-clay brick, as it is usually spoken of and termed in the trade. In times past there was, and even now there is, a great deal of opposition in certain quarters directed against the manufacture of brick by the dry-clay system, but this opposition, it must be conceded, has not the same basis that existed some fifteen or twenty years ago against this new system of brickmaking, which was then seeking to introduce itself into the trade. The introduction of the system of dry-clay brickmaking into the city of St. Louis, where it is probably now better developed than at any other point in the United States, was attended with many disadvantages and drawbacks owing to the prejudice at that time prevailing. It was then quite a common thing to see written

in specifications that "no dry-clay brick will be permitted to be used in the work described." It is hard now, however, to pick up a specification prepared by the architects in and near St. Louis that does not explicitly specify that "dry-clay brick shall be used," or else that "the brick employed are to be equal in quality to dry-clay brick."

In the manufacture of brick by the dry-clay system, vastly more depends upon the manipulation and treatment of the clay and the burning of the brick than is the case with reference to brick made from tempered clay. It is quite true that there are some clays which are naturally unsuitable, and which no amount of manipulation or experience in treating can be made suitable for making dry-clay brick. It is, however, the opinion of the writer that where one manufacturer fails on this account a dozen manufacturers fail for a lack of the proper knowledge of how to manipulate and treat the clay in its various stages, and in the burning. It is an axiom that different clays require different treatment, hence it does not matter how much experience a person may have had with the manufacture of dry-clay brick in a given place, for if the same person embarks in this industry in a new location there would be much both to learn and to unlearn, and a perfect knowledge of the new clay would be obtainable only after experience, close observation, and whole or partial failure in treating the clay.

In the manufacture of brick by the dry-clay system much more depends upon the burning of the brick than is the case with brick made from tempered clay. In other words, the writer desires to say that as between insufficiently burned brick of the two kinds, those made from tempered clay are much the best for durability and strength, for with the dry-clay brick the fire must supply that quality imparted by water and mixing in the tempered-clay brick, namely, a thorough kneading together of the entire body of clay of which the brick is composed. Brick made from dry clay, notwithstanding the fact that they may be subjected to enormous pressure in their formation, are at best no more than bodies of fine granulated matter, which

cannot have perfect cohesion until after it has been submitted to a heat sufficient in its intensity to fuse the fine granulated atoms together into one solid annealed and homogeneous mass, in which case the body of granulated clay is converted into a good and perfect brick. The writer has now before him samples of six brick of the different kinds, all made from dry clay; four of these brick are well burned, one is partially burned, and one is not burned at all. On breaking the partially burned or salmon brick there are disclosed the infinitesimal atoms or granules of which the brick is composed. The appearance of this brick after being broken is similar to that shown on breaking the unburned or green brick, and in fact the partially burned brick presents a more porous condition than the unburned brick, because in the case of the partially burned brick, the heat to which it was subjected was sufficient to destroy a large portion of the vegetable matter contained in the clay of which the brick was made. But the heat to which this partially burnt brick was subjected was not sufficient in degree to melt or fuse the granulated atoms together in one solid mass, such as is found to be the case with hard-burned brick, which improve in quality as they approach complete vitrification. In burning dry-clay brick it is not unusual to find some of them in the kiln that have been completely vitrified, and when broken very much resemble the appearance of flint or glass. Brick of this character, however, are the exception, as it is not the purpose or desire of the manufacturer to burn the brick to such a degree of hardness, and the brick so burned commonly occupy a position in the kiln in which they come in direct contact with the flames.

Salmon brick, molded by the dry-clay process, are largely employed for dwelling houses and other light work, and are not objectionable when they are kept free from damp positions, and when so employed answer very well for the purposes for which they are used; but in warehouse construction and similar heavy work brick of this character are practically worthless.

In selecting a clay suitable for the manufacture of brick by the dry-clay process, it will become apparent from what has

already been said in the foregoing part of this chapter that a clay that is weak in its texture and that contains a fair proportion of silica or of iron, lime or other fluxing elements, will make a better class of dry-clay brick than a clay of a stronger nature, which is hard to flux and which will come out of the kiln very much in the same condition that it went in.

The preparation of the clay is a very important part of the process of making brick by the dry-clay method, and in this connection there is always an opportunity to acquire knowledge by closely noting the peculiarities of the clays used.

After the clay has been dug the first step is to properly dry the clay, and usually a few hours' exposure to the sun and wind is sufficient for this purpose.

Richardson says, in his address delivered at the Second Annual Meeting of the National Brick Manufacturers' Association: "If the clay is near the surface, it is generally plowed to the depth of a few inches and left on the beds to dry. In the hot summer months the clay is usually allowed to remain exposed only about two hours, but in the spring and fall it is well to dry a day and have but one plowing. If too far below the surface, or on ground too uneven to admit of plowing, the clay, after having been mined with pick and shovel in the usual manner, is conveyed in carts to large drying grounds, over which it is dumped to the depth of about a foot. I know of no cheaper way of getting the clay upon the drying grounds than by carts—tramways cannot be used advantageously, as the clay must be dumped over so large a space. While the clay is upon the drying ground, it is gone over several times with a disk harrow, having about sixteen knives and working on a beam, and so arranged that it can be turned on a handle, and at the same time that the knives turn they cut and tear and break up the lumps and expose fresh portions to the sun and air. Some of the manufacturers of dry-clay brick, located near St. Louis, Mo., use an apparatus which travels back and forth over the plowed clay and which throws it up into ridges, and then men throw it into carts with shovels and it is then hauled to the

sheds. When the clay, or a portion of it, has become sufficiently dry, it is taken by wheel-scrapers into large sheds to be stored for future use. The proper dryness of the clay depends upon the time it is to remain in the sheds, and the depth or height to which it is to be piled. The object in storing large quantities of clay is not only to insure no stoppage during wet weather, but to allow the clay to sweat and become uniform in moisture throughout, as thereby alone can good results be obtained, and the longer the clay remains in the shed the better brick it will make. The average cost of getting the clay into the sheds in proper condition ranges from fifty-five cents to seventy cents per thousand when the clay sheds are not more than 500 feet from the banks. The drying grounds are between the clay beds and the sheds. The entrance to the shed, if only one, is in the centre of the side toward the drying grounds, so that while one end is being emptied for manufacture the other can be filled. From the shed the clay is taken to the elevator opposite the entrance, either by scraper or tram cars, and raised to a height sufficient to allow of its shooting into the pulverizer screens and presses without being again elevated. The manner of pulverizing varies much with different clays, generally two pulverizers being necessary and two cylindrical revolving sieves. No single pulverizer will prepare for the press all the clay it receives, though sometimes one is made to do the work by putting through it a second time that which has not been pulverized fine enough. A sieve is placed over the press to prevent anything but fine clay from being admitted. Such, briefly, is the method of preparing the clay for dry-press brick-making, simple enough in description, but in practice more complex, and involving more difficulties than one who has not tried it can have any adequate idea. The great problem is to get the clay fine enough and at the same time of the proper degree of moisture. The clay should go into the moulds uniform in fineness and dryness, moist enough to be pressed hard, and dry enough to allow of the brick being set immediately in the kiln thirty to forty high. We usually say that the clay is of the proper dry-

ness when if squeezed in the hand it will just hold together and retain form after the pressure has been removed. To get it into this condition is not an easy matter. If the clay is too moist it cannot be pulverized fine enough; if too hard it cannot be pressed hard enough. Brick presses will generally work damper clay than pulverizers. Strong, plastic clays work best, as they can be pressed in a drier state than weak, sandy clays. In considering this question, however, regard must always be had to difference in clays and machinery. It is of the greatest importance that machinery be selected suitable to the clay. No machine has ever been constructed that will work successfully all clays, and some machines are failures under ordinary circumstances, and have ruined many a man's business.

"To one about to undertake the making of brick by the dry process, no better advice can be given than the following: First, secure the services of a competent brick engineer, with long experience in the process, to lay out the yard, select and arrange the machinery, and put everything in good running order. Do not mind the salary you may have to pay him; if he is the right man he will save you ten times the amount, and perhaps prevent financial ruin.

"It is important to store a large quantity of clay in sheds, enough for two or three months' run, or longer. With some clays this is absolutely necessary in order to get good results. Now, the finer the clay, the freer from stones and lumps, the sooner will it become fit for use. The plan of setting a coarse pulverizer and stone separator just at the entrance to the shed is a good one. This would make the further separation of the clay much easier, and would not increase the cost to any appreciable extent. One difficult operation, however, still remains, before the clay is fit for the press. Supposing the clay to be well-tempered, of the proper degree of moisture and uniform throughout the pile, yet it is not fine enough to be made into a good brick, and must be put through another pulverizer. The clay may be dry enough to press well, and yet so damp as to clog the pulverizer and cause so much waste in tailings that the

presses must be stopped occasionally for lack of clay; not only this, but the pulverizer will sooner wear out and need repairing, perhaps necessitating more stops. In order to make the business prosperous, the process must be kept running, for every minute that a press making 15,000 bricks a day is stopped, a loss is entailed of 25 to 50 cents. Five to ten dollars a day may easily be lost in this way, and perhaps at the end of the season leave a balance on the wrong side of the ledger.

"Some manufacturers may have no trouble in this or may have success in obviating it. An ingenious man will often provide a remedy. The clay can be easily pulverized dry, too dry for the press, and afterwards dampened by placing a steam pipe, perforated with small holes and wrapped with cloth, just at the end of the shoot leading from the pulverizer."

DRY-CLAY PULVERIZERS.

The machinery for pulverizing is a matter largely determined by the nature of the clay to be handled. As a general thing, if the clay is reasonably free from stone, a dry pan crusher is the best, although by no means the cheapest. The pan having a perforated bottom, the clay running through the perforations falls into an elevator boot, and is then conducted as high as the building will permit. When up to its furthest height, it is run over inclined screens lying at an angle of about 45°, the clay fine enough for the press runs through the meshes of the sieve, while the tailings are conveyed back to the dry pan to be reground. There are other ways to prepare clay, requiring a somewhat less expensive plant, and which do very well, provided the clay is not too strong. Smooth rolls geared together, having a differential motion, are the prototype of this class of machinery, usually called disintegrators. These have been greatly improved by the many excellent machines made by different makers. The object to be attained, and which has made a departure from the old-fashioned smooth rolls a necessity, is to prevent the clay from being laminated or rendered flaky. Clay, instead of being crushed or flattened, should be

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treated exactly in the opposite way, viz.: It should be torn to pieces, and to attain this object to perfection is the goal to be arrived at by the manufacturers of pulverizing machinery. In using a dry pan this difficulty is to some extent, although not altogether, obviated by the continued stirring up of the clay before the rollers. It is sometimes the practice to run clay through the reels after going through the disintegrator, instead of over the inclined screens, as before mentioned.

When stones are mixed with the clay in the bed, the ordinary method of manipulation must be abandoned. It is not long since that a bed of clay having many stones interspersed throughout its mass was considered practically useless for dry-press front brick, no matter how excellent the clay may have been in itself. As a general thing, when this is the case, it is only necessary to adopt a method of manipulation by which the stones are taken out of the clay and thrown to one side. Unless there are a very few, it is poor practice to crush them up with the clay. Inventors in the line of clay pulverizing machinery have striven hard to produce a machine that will accomplish easily and surely this much-to-be-desired object.

From the pulverizers the clay is next carried by means of an elevator belt or otherwise to the hopper of the brick machine.

There have been of late so many improvements made in machines for moulding clay by the dry-clay process that there are now in the market a large number of such brick presses which are claimed to be fully adapted to the purpose for which they are designed. In selecting a machine of this character care should be had that it be as simple as possible in its mechanism, that the material used in its construction is of the best quality. Owing to the enormous strain to which machines of this class are exposed, a large amount of money is annually lost because of the poor quality of the iron or steel used in castings or other parts, thereby causing breakages to occur which would not otherwise take place. It of course becomes apparent that in matters of this character the purchaser has to rely largely upon the reputation of the makers of the machines,

and the subject should receive attention at the time when the contract of purchase is made.

DRY-CLAY BRICK MACHINES.

There has been unquestionably a great advance in recent years in dry-press machines. Those that pressed the clay from one side only are now universally condemned, as it left the side of the brick furthest away from the pressure soft and without strength. There is no doubt, however, but they were the forerunners of our present presses. It was soon discovered that to make both sides of the brick equally hard and strong, it was necessary to make the machine so that both sides of the brick should receive equal pressure. This idea insured both edges strong and sharp. But what about the centre? Ah, "there's the trouble." An ugly granulated central seam running around the middle of the face of the brick was for years the unmistakable mark of a dry-pressed brick, and that is where those manufacturing by the re-press process made their strongest argument. They could point with the finger of pride to their brick having no such ugly defacement, and it cannot be denied that their argument was a just one. The dry process could never hope to compete successfully with the re-pressed method until this fatal objection was overcome. It is safe to predict that machines having this drawback are doomed, and that they will in the immediate future be abandoned. In some machines it is claimed that this objection has been entirely overcome.

Another important question regarding a dry press is its strength. To make a good ringing brick the particles of clay must be pressed together into as dense a condition as possible. Should it not receive the requisite pressure, the brick will be shaky and fail to have a genuine ring, even when the clay is of an easily vitrifiable character. To withstand this pressure great strength is required in the machine.

The greatest difficulty that machine men have to contend with is the lamentable lack of knowledge amongst those having charge of the machine after it leaves the shop and goes into

actual service. It is an easy matter for a careless attendant to ruin a machine and spoil the reputation of its builder. A frequent mistake made by those using dry-press machinery is the straining of the machine to its utmost capacity. In pressed brick it is the quality of the product that tells and not the quantity, and very often the former is sacrificed to the latter. Of course, when the dry process is adopted to make common brick, then in that case it is necessary to work up to the limit with little regard to the beauty of the product.

DRYING.

If the brick are to be dried in the open air, the nature of the clay should be studied so that the current of air admitted to the drying apartment will not be sufficient to crack, warp, or in other way injure the green brick. If the brick are to be dried by artificial means the method employed will depend largely upon local circumstances. If an abundance of fuel can be obtained near by, and at low cost, it may in some instances be cheaper to place the moulded brick upon cars suitably built of iron, and have them conveyed to a drying tunnel, at one end of which there is a furnace, and at the opposite end a chimney or stack, in which case the brick will be dried by coming in actual cantact with the flame and heat of the furnace. In some cases these drying furnaces are so constructed as to utilize the heat derived from kilns of brick in process of burning, and from which the water-smoke or steam has been previously driven off. In all such methods of rapid drying, care should be observed that the surfaces of the brick are not dried so rapidly as to cause the shrinkage of these surfaces, and hence the cracking, which greatly disfigures the appearance of the brick and lowers their commercial value.

A large number of works manufacturing brick by the dry-clay process use steam for drying purposes, the steam-pipes being so located in the drying chamber as to give a uniform temperature throughout, exhaust steam being utilized for drying the brick during the day, and live steam being employed

at night. Where steam is used for drying the brick it is essential that the drying apartment should be provided with adequate means of ventilation, in order that the moisture generated from the brick may be carried off as rapidly as possible.

BURNING.

The manner of setting dry-clay brick does not differ materially from the method of setting tempered-clay brick. The kiln having been thoroughly daubed on its interior faces and all holes and cracks faithfully stopped, a careful examination of the floor of the kiln should be made, and if coal is the fuel to be employed for burning the brick, all grate bars should be inspected and defective ones removed or repaired. In burning dry-clay brick it is absolutely necessary that the floor of the kiln be kept as dry as possible, for if there be damp places the bottom courses of the brick are liable to crush and cause serious inconvenience in firing and in estimating the natural settlement of the kiln in the final burning. Where there are places showing moisture it is better to use salmon brick for the bottom course; the difference in the width between the salmon brick and the green brick can be made up with loam placed on the bottom of the kiln. The height to which the brick are to be set depends largely upon the nature of the clay and of course upon the style and condition of the kilns. The writer in the manufacture of this class of brick employed the open or Dutch kiln, and usually set the brick about 42 high, 14 courses in the arches, 14 courses on the lower bench, and 14 courses on the upper bench, and used two courses of burned brick for platting. The object in using the two courses of burned brick, or rather salmon brick, for platting was to hold the heat as long as possible, and then it was found by experience that where the green brick were used for platting it was difficult to walk over them in tightening the platting courses without breaking or crushing, and where the brick were crushed defective places would occur in the kiln to a depth of four or five courses below these defective or crushed brick, and the loss entailed was greater than the cost of using the salmon brick for the platting courses.

The brick having been set in the kiln and the bestowing properly put up, daubed and braced, and every alternate brick of the top or platting course set upon its end, the kiln of brick is ready for burning. In firing dry-clay brick, no matter how thoroughly or carefully they may have been dried, it is absolutely essential that the early stages of burning should be conducted cautiously and that no attempt should be made to drive off the water-smoke too quickly, only a very light fire should be made in the mouths of the arches, and only on that side of the kiln which will allow the smoke to be driven or blown entirely through the arches, fire being made only on the windward side. The fire should be increased very slowly, and in some instances ought not to be crossed inside of seventy-two hours. The great object in the early stages in burning dry-clay brick is to drive off the water-smoke from the brick without increasing the volume of air contained in the brick and disseminated between the granules. If the air thus contained in the brick should become heated too rapidly, it will expand and it will be almost impossible at any future stage of the burning to bring the granules of clay in the same intimate contact that they were before the expansion of the air, and then, again, from the swelling of the brick injury results to the kiln. Time spent in the early stages of burning this class of brick should not be considered wasted; no effort should be made to push the burning until the limit of water shrinkage has been reached, which is just before the last particle of water-smoke has disappeared, and from this point on to the final firing the kiln of brick should be pushed more quickly and under heavier firing than is usually given to tempered-clay brick. Perhaps it may not be amiss to repeat more fully at this point a former explanation of what is meant by "the limit of the water shrinkage." The hydrous silicate of alumina, or pure clay, being infusible even under the most intense heat, possesses no power of shrinkage in burning. Brick clays, however, are not pure clays; they are mixed with the alkalies, or alkaline earths, and they are fusible in proportion to the admixture. Now aluminum

hydrate, like silicic acid, is capable of assuming the gelatinous form, in which, owing to the peculiar arrangement of the atoms, these compounds are able to take up a large quantity of water swelling or binding together sandy or earthy matter in a fine state of division. On removing the water by drying, the original mass shrivels up; this is termed shrinkage. Either on drying in the air or on burning, the atoms of clay approach one another more closely, the accompanying admixed constituents also at the same time being drawn together. An increase of density and diminution of bulk thus occur. It has been shown that, by gradually drying brick clays at a temperature increasing to the necessary point, the shrinkage did not continue until the clay was quite dry, but ceased before this point was reached.

To a certain stage the shrinkage exactly expressed the loss of water; at this point it suddenly stopped, just as the clay particles came into contact. This point is termed the "limit of shrinkage," and the water dissipated to this point is distinguished as the "water of shrinking," and that subsequently driven off as the "water of porosity." The sum of the two is total water, and is the "limit of water shrinkage."

The proportion of pores in the dry clay is constant, that is, independent of the water originally contained. From the fact that the proportion of pores in several chemically different clays is nearly equal, it may be inferred that the smaller atoms of clay have a regular spherical shape, and this view is confirmed by microscopic observations.

In brick made from tempered clay there are thus a vast number of these little spheres at equal distance, and surrounded by a greater or less quantity of water. In dry-clay brick these little spheres are brought more closely together than in tempered-clay brick. The distance between these particles is so small that the attraction between them is considerable, so that a system of capillary tubes is formed, in which expulsion of water by pressure is so opposed that neither the power of attraction of the spherical atoms for one another, nor their verti-

cal downward pressure, will permit the water to penetrate through the tubes. In shrinking, as water evaporates on the surface, a fresh supply is drawn from the interior of the mass, through the fine capillary tubes mentioned above, the particles approximating throughout the whole mass, in obedience to their power of attraction; and this process continues until the atoms come in actual contact, and then room for water is afforded only in the spaces between the particles (water of porosity). In meagre clays these fine spherical atoms envelop the irregular-shaped particles of foreign matter. On trying the effect of additions of very fine sand to some washed clay, it was found that to a certain point the shrinking power of the clay increased with its progressive meagreness (the water being constant), and the porosity decreased. This point is termed the "point of greatest density of the mass."

From the point of greatest density further impoverishment diminishes the shrinkage for an equal amount of water in the pores, but increases the porosity.

Hence it is that brick made of moderately strong clay by the dry-clay process are not in condition to commence to receive hard firing until just before the last of the water-smoke leaves the kiln.

The proportion of fuel required to burn a kiln of dry-clay brick, because of their greater density, averages from one-sixth to one-quarter more than for brick made from tempered clay. The amount of settling to which the kiln is to be subjected depends, of course, upon the nature of the clay, and this can be determined only through practical experience. After the kiln has been burned it should remain closed for four or five days, and even longer, if the time can be spared, as kilns of brick made from dry clay are injured by being exposed too quickly to the cooling process after burning.

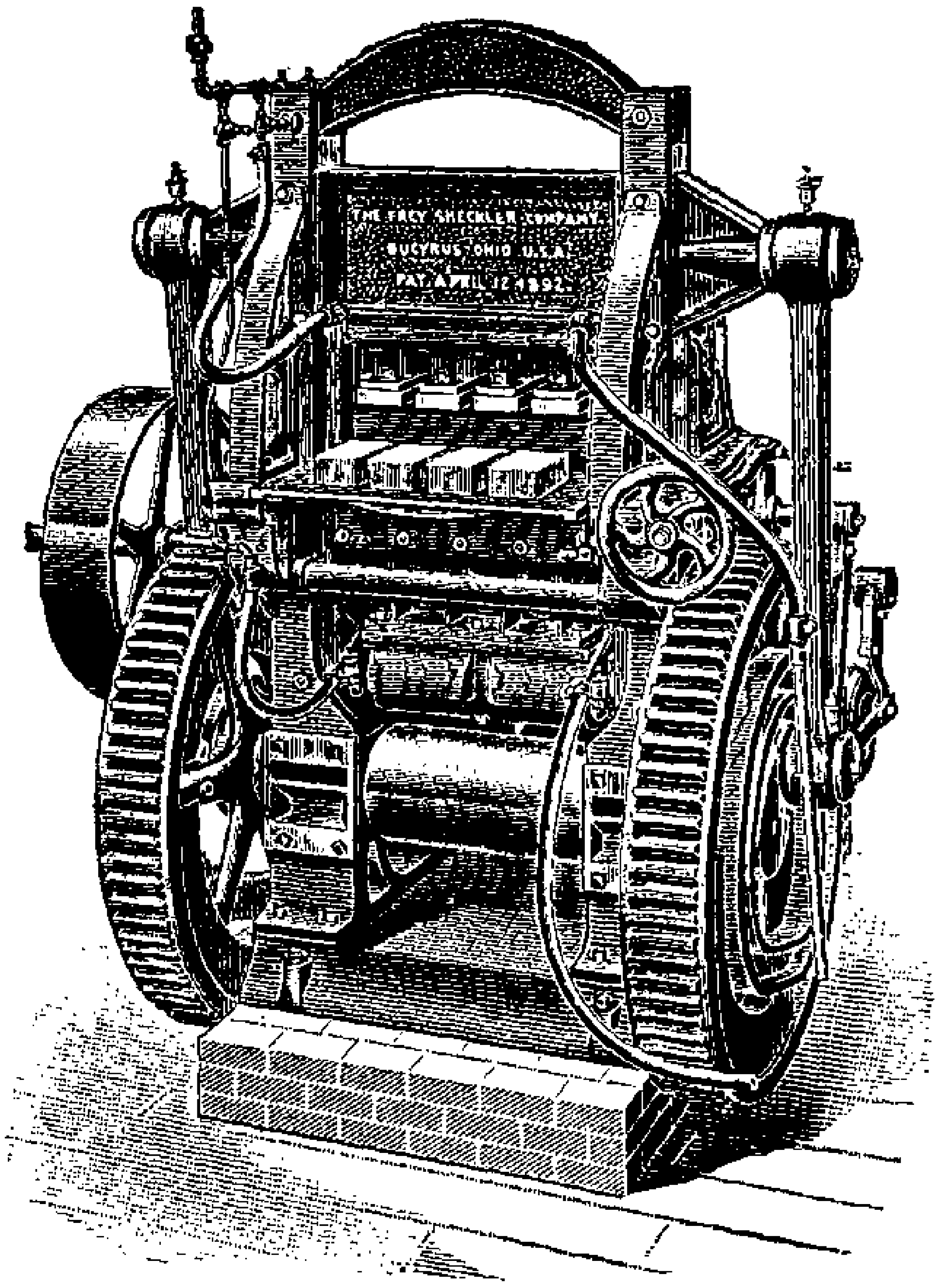
SEMI-PLASTIC BRICK.

There are recent modifications of machinery which provide for added moisture to the clay, and which have resulted in the

production of brick which fairly overcome the former defects and obviate criticism, making the brick a semi-plastic rather than a dry-clay brick.

This machine is shown in Fig. 67, and is made by the Frey-Sheckler Co.

FIG. 67.



SEMI-PLASTIC BRICK PRESS.

In the construction of this machine the manufacturers have endeavored to so design it that it will completely fulfil the most exacting conditions, and they claim for it the following advantages:

First: It exerts a greater pressure than any other machine of its class, and this pressure is retained on the brick until they are delivered from the mould.

Second: Simplicity of construction, easy accessibility, and immense strength.

Third: It leaves no granulations on the outside surface of the brick.

Fourth: All the rectangular edges of the brick are perfect.

This machine is built in two sizes, viz.: Two and four mould. Capacity of two mould, 10,000 to 12,000 brick per day, and will consume about four horse-power. Capacity of four mould, 20,000 to 25,000 brick per day, and will consume about eight horse-power.

These machines have been thoroughly tested, and are sold under a guarantee.

CHAPTER VIII.

THE MANUFACTURE OF PRESSED AND ORNAMENTAL BRICK.

PRESSED BRICK.

PRESSED or front brick are produced by a combination of the hand-made and the machine processes. The finishing of brick of this class is sometimes done in a press run by steam-power. The usual way is to mould the brick by hand and make them slightly larger than the size of the press-box in which they are to be finished.

The moulding, drying, and pressing of front brick are conducted entirely under shelter; the hand-press gang is composed of three members: the moulder, who also does the pressing; the temperer, who also does the wheeling of the clay; and the off-bearer, who also rubs the finished brick with very fine moulding sand.

A day's work for the press-gang is to temper the clay, mould, press, and finish one thousand one hundred and sixty-seven brick. Pressed brick are seldom hacked on edge in the sheds, but are laid flatwise, each pile being a separate one, and a space of about three inches is left around each hack; they hold shape better in this manner of drying than if hacked on edge, and after they have been pressed they are hacked differently, as will be explained.

For the information of brick-makers in distant places, where pressed brick have not been made, we elaborate further upon the general plan of making them by hand.

It is important that the clay should be well tempered, the clay-tempering-wheel producing the best. The brick should be moulded free from flaws or sand-cracks, and the mould, when in use, should be kept well cleaned. Those in general use in

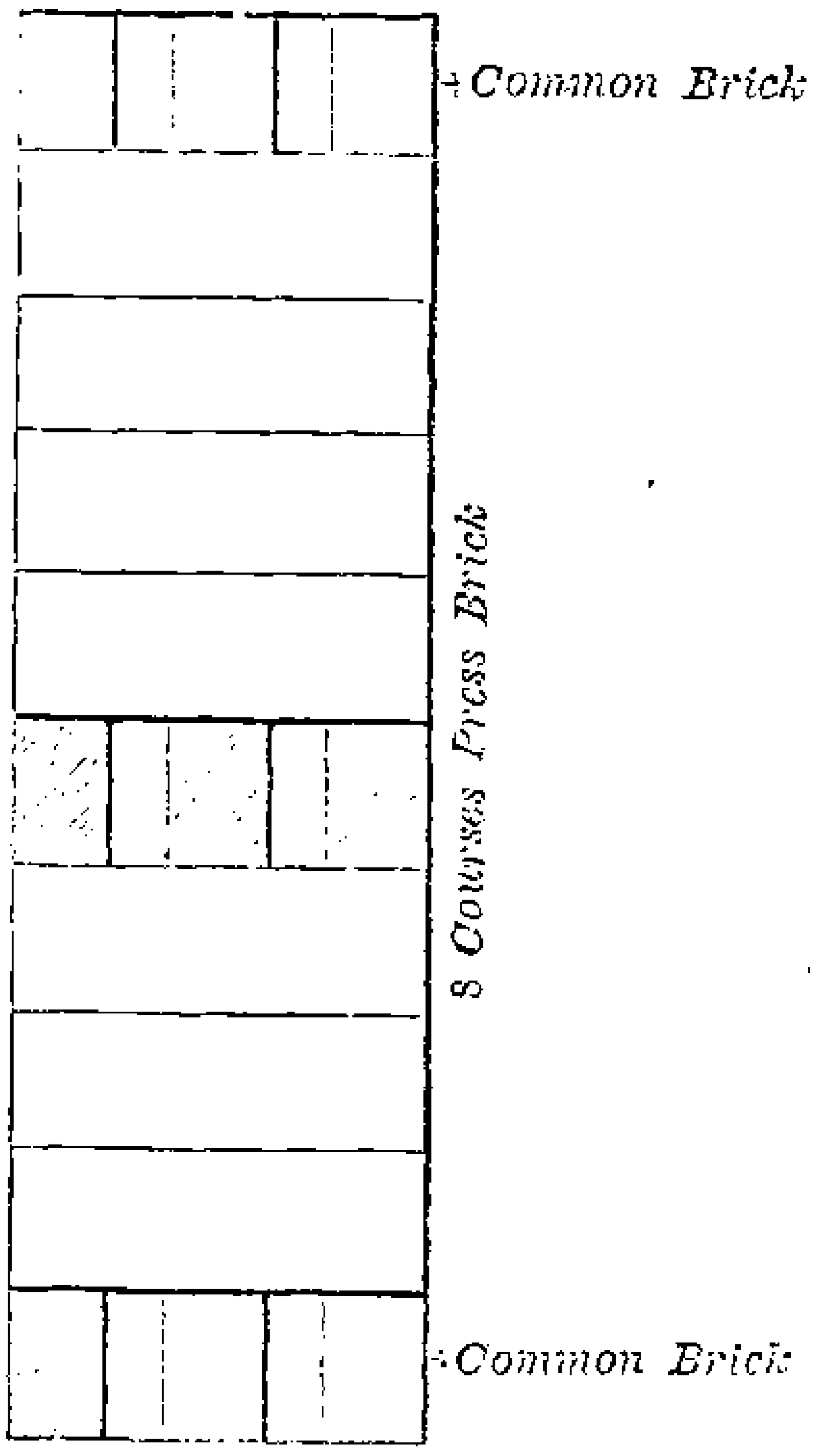
Philadelphia are known as the "single cast-iron moulds." The moulding sand is an important item in making pressed brick, as the color and smoothness of the brick depend on it. A sieve having about sixty meshes to the lineal inch is used for preparing the sand for moulding the brick. The brick are placed flat on the floor, and when pretty dry, a light sieving of sand is put over the faces. They are then turned over that they may dry more regularly. Sheds built expressly for the purpose are also used for pressed brick. The roof is made to open so as to admit wind and sun when required. Where the brick dry too fast, a piece of damp carpet can be laid over them and sprinkled occasionally with water. When the brick are in a proper state for pressing—say, when they can be handled without finger-marks—the press is taken to the brick by placing the press on boards, the brick are carefully put into the mould, great care being exercised that they are not marked in dropping them in. There must be no finger-marks on them, and all "crumbs" must be wiped off the face of the mould; also off the lid. After the brick are pressed they are generally laid flat, five or six high, and when partly dry they are slightly rubbed with the hand and piled pigeon-hole shape, which allows further drying. In some cases they are piled in squares, edgewise, five or six high. When dry enough, they are placed on barrows, with strips of wood or soft blankets between each course, and taken to the shed to remain until required for burning. It is highly important that the mould lid and plate of the press shall be kept clean when in use. Occasionally raise the plunger plate, and wipe off any dirt that may have accumulated on it, and apply a slight oiling to all the parts. When the day's work of pressing is ended, make it a fixed rule that the presser shall take out the plunger, clean the mould lid and plate, oil the surfaces and replace. Occasionally, while working, the presser should clean the plunger and keep it always well oiled, as should be all the wearing parts of the press.

The pressed brick are usually set eight courses high in the kilns, but we have seen them carried ten or twelve courses in

height in the city of Philadelphia. The top course does not usually extend closer than the fourth course from the top. They are also set differently from the way in which common brick are placed, the desire being to preserve the faces which are to be exposed in the wall of a building. There is not the same amount of crossing or "checkering" of this class of brick as in the common stock.

The bottom, one middle, and the top course, are crossed or checkered in setting eight high, and Fig. 68 will show the manner of placing them in the kiln. The brick are set one directly over the other on edge; the "cross-ties" shown are to hold the body and keep the pressed brick from "wabbling" or slanting from either side. Great care and experience in setting as well as in burning kilns containing quantities of pressed brick are very essential. Too hard firing in settling the kiln is liable to cause all the pressed brick to "tumble" or fall, and the fires at this stage are consequently lighter and more frequent than when the kiln contains only common brick. The pressed brick are also handled much more carefully than common brick, being taken up one at a time, placed lightly on barrows, and are carefully handled and tossed also one at a time to the setter. No extra money is paid to the setting gangs for handling pressed brick; the work is included in the task.

FIG. 68.



ELEVATION SHOWING MANNER OF SETTING PRESSED BRICK IN THE KILN.

In all stages the "gluts" as well as the finished green pressed brick should be protected from unequal drying; the sheds in which they are made should have movable slat sides, which are closed during periods of strong winds.

When the "gluts" for pressed brick are made by machinery, the clay should be wet, and the brick, when they issue from the machine, should be soft enough to allow the finger to be forced into them. The gangs which re-press machine-made front brick are composed of four persons, if handled on barrows, and three if handled in the brick cars, the members of the gang being the presser, off-bearer and rubber, or sander. The brick are run through in a hurry, three thousand being a day's work. Brick made in this way are not usually suitable for the lower story fronts of fine buildings; but, when economy is an object, they can be used in the upper portions where their defects cannot so easily be discovered. This is hardly honest, but a great many neat fronts are thus put up in neighborhoods that would not justify the employment of first quality and high-priced brick.

When care is taken with every stage of the work, and the "gluts" are made very soft, and well and thoroughly sanded and rubbed, it is possible to produce pressed and ornamented brick which are not only good in appearance, but which are strong and durable, and which can with safety be used in place of first-quality brick for cornices and other work occupying a high position in buildings.

Geo. Carnell, of Philadelphia, Pa., the well-known manufacturer of hand and power brick presses, gives the following concise directions for making fine front brick:

1. It is important that the clay should be well tempered, a clay-tempering wheel producing the best.

2. It is necessary to have sheds built expressly for that purpose, the roof being made so it can be opened to admit sun and wind when required; doors are also made to protect the sides of the shed in case too high winds prevail. In sheds built this way, the brick can be dried with better regularity.

3. The brick should be moulded free from flaws or sand cracks: the moulds, when in use, must be kept well cleaned by the off-bearer, as the accumulation of sand or dirt on the sides of the moulds, if not scraped off, will make a variation in the sizes of the brick when they come to be pressed.

4. The brick are placed on the floor to dry. When nearly dry a light sieving of sand is put over their faces, and they are then turned over that they may dry more regularly. When the brick dry too fast a damp carpet can be placed over them and sprinkled occasionally with water.

5. When the brick are ready for pressing, say when they can be handled without finger marks, the press is then taken to the brick (or *vice versa*); the brick are then carefully placed in the press mould, care being taken that they are not marked while dropping them in. The brick must be kept free from finger marks.

6. The mould, plate and lid should be kept clean; a sharp-pointed hard wood stick is best to clean the corners of the mould out with. This should be done, and the mould wiped out every few brick; occasionally it will be found necessary to raise the bottom plate and scrape the dirt from around the sides; after cleaning apply a little oil.

7. From the press the brick are carried with paddles and laid on their flats, about six high.

8. When the brick are partly dried they are rubbed carefully with the hand and hacked on their edges, pigeon-hole shaped, for drying. By pigeon-hole hacking we mean placing the brick two on two, and reversing them every course. After they have become hard enough to handle without danger of injuring them they are placed on barrows, with pieces of soft carpet or blanket between the courses; they are then hacked in sheds and are ready for the kiln.

9. After the day's pressing is finished take the plate and plunger out of the mould, scrape all the dirt off, wipe clean, and oil the mould, plates and plunger. By keeping the press and mould clean it will give better satisfaction.

The following paper was read by Mr. William Roberts, of Trenton, N. J., at the Fifth Annual Convention of the National Brick Manufacturers' Association, Thursday, January 22, 1891. The paper is entitled, "Press Brick: Their Manufacture and Use."

"I hardly think it necessary for me to go into a lengthy description of pressed brick or their manufacture or use in the past, as that will not concern the members of this Association so much as a general discussion and interchange of ideas and views upon matters appertaining to their manufacture in the present and for the future. Of course, we shall take our experience of the past as a foundation for our present ideas.

"The term pressed brick was originally meant to apply to a brick that should be first moulded and then re-pressed, as that has been the customary way of producing brick heretofore specified or looked upon as pressed brick. But of late years there has been manufactured throughout a large section of the country a large number of brick that of course might be termed pressed brick. For instance, all the brick that are made with what are called dry-clay brick machines are certainly pressed brick, as they are pressed into shape by the same kind of a process as are our regular pressed brick. The only difference in their manufacture is that in making brick with dry-clay machines, the brick are pressed into form direct from the raw material, while what we have always heretofore termed in the east as a pressed brick have in all cases been moulded into the form of a brick before going through the process of re-pressing, and this is the kind of a brick that we shall particularly allude to in the reading of this paper.

"About the first pressed brick that we know of as having been made in the east for the general trade in any large numbers were in the cities of Philadelphia and Baltimore; in fact, we do not think that previous to twenty-five years ago there was any place that manufactured pressed brick outside of those two cities, that is, for shipping to the general trade. Of course, there were some few pressed brick made in a small way in other places for local consumption. About a quarter of a century ago the brick manufacturers of the city of Trenton, N. J., commenced to manufacture a few pressed brick for the New York market, and they have been steadily increasing their output up to the present time. In the year of 1870 the city of

Trenton produced about 1,500,000 of regular pressed brick. But at the present time we produce annually about 20,000,000 of pressed brick, all of them being made in the regular way, by first being moulded by hand one at a time, and then re-pressed with hand presses.

"We have no statistics showing how many pressed brick are made in other cities, but from the best information that we have been able to obtain, we judge that the city of Trenton is about the second city in the number made annually of this particular class of brick, the city of Philadelphia being first and Baltimore third.

As far as brickmaking is concerned, we think that the city of Trenton is what might be called a pressed-brick city, for the reason that a specialty is made of that class of brick by all the yards carrying on business there (60 per cent. of all the brick manufactured in the city of Trenton are pressed brick), which we think is the largest percentage of this class of brick made in any one city in the United States.

"We shall now endeavor to give you some of our ideas on the making of pressed brick, ideas which we have gained through a practical experience in their manufacture, and will cheerfully invite any discussion on the matter.

SELECTING AND PREPARING THE CLAYS.—"WEATHERING."

"First in order we will try and give you our ideas on the selecting and preparing of the clays or raw material to be used in the manufacture of pressed brick. Of course all sections of the country do not have just the right kind of materials that will produce a first-class pressed brick, and where clays are found suitable for the purpose, they will differ very much in their natures in one locality from what they are in some others, and therefore the manufacturer in selecting and preparing his materials is compelled to be governed according to circumstances, that is, he must make the best use of what different materials he may have at hand, for the reason that pressed brick as well as other building brick will hardly permit, or will pay well

enough to allow the shipping of the clay any great distance. Now, although the burning of pressed brick is the last process which the clay goes through before being finished into pressed brick, it is about the first step to be taken into consideration. In selecting and preparing our raw materials we must first know what the brick that are to be made from them will be when burnt, or else all of our work at the start will be of no use; and I think all of you will agree with me when I say that to prepare materials that will make a good pressed brick in a raw or green state is but very little trouble, but to get at what kind of materials will make a perfect pressed brick after it has gone through the test of firing requires much care and study; and we think that the only way, or at least the best way known to us at present how to combine materials successfully for the making of good pressed brick is by a practical experience, that is by the making of different trials and experiments with whatever kinds of clay, loam or sand that the manufacturer may have at his command.

"Of course a chemical analysis of clays is all right as a matter of theory, but where so much raw material is required to be used as is the case in the manufacture of brick; I think that the knowledge and experience gained by practical working is by far the best; of course it requires time and expense to get this kind of experience, but it will certainly pay the manufacturer the best in the long run.

"Some of the main points to be considered in combining materials for pressed brick is to get a combination that will stand enough firing to produce a brick of sufficient hardness for all purposes without too much warping or shrinkage, and at the same time to retain a desirable color, as we often find that in using too much of a clay that will fuse or melt easily, the brick when burnt are warped and crooked and shrunk so much that they will be of many different sizes, those that are burnt the hardest being smaller than those that are not burnt so hard, and on the other hand some material will stand more firing and produce a brick that will be of a fair color and keep straight

and of full size when burnt, but probably they will not be as tough and strong as are desired. Thus it happens very often that by combining two or more materials together we get the results for which we are trying. There is such a wide difference in materials that one manufacturer may have at his command from what others may have, that there can be no set rule for the combining of materials for pressed brick, that will apply to every locality or that can always be followed with safety. The preparation and proper pugging or tempering of clays for pressed brick is quite an important matter, but with the improved machinery that has lately been brought into use for that purpose it can now be done with very little difficulty.

"The question of weathering clay before being used for the manufacture of brick is a thing that has been advocated always as beneficial. We claim that the benefits which a manufacturer will gain by the weathering of clays before using depends a great deal upon circumstances. In the first place, we do not think that a brick can be any better from having the clay exposed to the weather for a long time than it can by using the clay direct from the bank, providing that the clay be thoroughly worked and mixed before being used.

"So you can see that what we mean by this is, that the weathering of clay is of no real benefit to the finished article, but will only lessen the labor and expense of mixing and preparing of the clay before use.

"This matter, as well as some other points appertaining to the manufacture of pressed brick, must be governed according to circumstances. In some places the clays used are of a very stubborn and strong nature, and will not yield readily to the common methods used for tempering and mixing unless they are first exposed to the weather for a long time, and then they will yield very readily when the water is placed upon them for the purpose of soaking and mixing. It is much cheaper to expose material of this kind to the weather than it would be to use extra machinery for the purpose of reducing it to that state that it can be worked by the ordinary methods used for temper-

ing. The majority of clays that are used for the manufacture of pressed brick can be worked at a reasonable cost of labor and expense without the process of weathering, and for these reasons we claim that it is much cheaper to use the material direct from the bank, and we think it can be done without in any way affecting the quality of the finished article.

"There is one expense attached to the weathering of raw material to be used in the manufacture of brick, besides the cost of the extra handling which is necessary, and that is in the percentage of loss to the materials by being exposed a long time to the elements. We have made some tests of what loss there is in weathering clay by digging it up in the early winter and letting it lie until the next summer before using it, which is about the period that it has been the custom for brickmakers in the eastern part of the United States to weather their clay, and we have found that the actual loss to materials has been fully fifteen per cent.

MOULDING THE GLUTS.

"In coming to the first crude form in which pressed brick are generally moulded after selecting and preparing the clays, we shall more particularly speak of such brick as they are generally made in the East, that is, what is termed a regular hand-made brick. They are, as you all probably know, first moulded in "glut" form one at a time by hand, and then allowed to dry to a certain consistence before they are re-pressed. We have found that the better we can have this first "glut" or crude form of the brick moulded, the better the finished article will be.

"Many pressed brick manufacturers have been led into error by supposing that any way of getting the first form of the brick for re-pressing is good enough, that is, they will naturally think if they only get the amount of clay required for a brick in almost any shape or form, it is all that is required, taking it for granted that the press when it comes to the repressing must of course make a brick from it that will be perfect in both shape

and quality. This is a great error, for the reason that there is very little material from which we have ever seen press brick made that would not show the defects caused by improper moulding, even after the brick might be most carefully re-pressed.

"One of the first qualities that is required in a good press brick is for it to have a fine surface or skin on the sides and ends of the brick, as they are the parts that are exposed to view when laid in the building.

"This skin should be smooth and uniform and not broken, and we find by experience that the only time to get a fine surface to the brick is in the first moulding of the "glut" brick. As you are aware, that is done by the proper application of a coating of moulding sand on the outward surfaces of the brick in the process of moulding. That is, each proportion of clay required to make one single brick is thoroughly rolled in fine moulding sand and the moulds are also coated with it, and the sand not only gives the brick a fine skin or coating, but it also causes the brick to slip freely from the moulds. This, I think, has been one of the main difficulties that have been met with in making brick by machinery and then re-pressing them for front brick.

"In making brick with what is termed a soft-clay machine, the clay, as a rule, is forced into the mould in a raw state, and we can only depend on what sand we can get on the inside surface of the mould to form the coating of the surface of the brick when finished.

"Then again, the sand that is generally required to be used in making brick with a soft-clay machine in almost all cases is too sharp to form a coating to the brick, for the reason that very sharp sand will not combine properly with the clay to form the skin to the brick. You will find that when too sharp a sand is used, instead of adhering to the clay and forming a smooth unbroken surface to the brick, it will become detached as the brick dries and rub off very easily, and of course leave the brick with a rough and broken surface.

"In moulding brick with what is called a stiff-clay machine and then re-pressing for front brick, we do not think this trouble is met with to such an extent, for the reason that no sand at all is required to make the brick slip, as the clay is forced through the die of the machine in a square form called the web, and then cut by wires into the individual proportions that are required for each single brick. By taking a very fine sand (powdered clay would answer as well) and applying it to the web of clay as it passes from the die of the machine, we think that the matter of coating the surface of the brick to form the skin that we have mentioned can be accomplished if the sanding is properly done.

"Now in giving you what we shall only call our own ideas concerning these two classes of brick machines that are most used in the making of the 'glut' for pressed brick, we will state that we have never used any kind of machine for the making of pressed brick at our yards, nor do we know of any ever used in Trenton; so you can see that we are not talking in favor of any one brick machine, nor on the other hand do we condemn any; but we have simply mentioned these facts about them in regard to their making a good pressed brick, and to bring out any good point any of you may have to give us on the use of brick machines in the moulding of 'gluts' for pressed brick.

DRYING THE "GLUTS" BEFORE RE-PRESSING.

"The drying of the brick before they are re-pressed, we think, is one of the most important things that we have to consider in their manufacture. To get a good pressed brick it is necessary that they should be dried regularly and not too fast, for if they are dried too fast the outside of the brick is liable to get crusted, while the middle will be too soft, and then when they are re-pressed the corners are liable to crumble or not be filled out properly.

"The best and most economical way to dry a pressed brick is yet an open question to be determined in the near future by manufacturers in the East.

"There has been little progress made in the artificial drying of pressed brick, but we think the time will come, and it cannot too soon, either, when the drying of pressed brick by artificial heat will be accomplished so as to make it a permanent success; and when that time does come not only the manufacturer of pressed brick will be benefited, but hands employed in their manufacture will be benefited fully as much.

"One of the benefits to the manufacturer in drying pressed brick by artificial heat will be that he will not require over about one-quarter of the yard room that is now necessary to dry pressed brick by the sun and air, and the business can then be conducted so as not to be dependent on certain seasons of the year, or subjected to the annoyance and loss from storm and bad weather.

"The employe will of course be benefited by having employment the whole year, instead of having to depend on the weather for what work he gets, as is the case now.

RE-PRESSING.

"The re-pressing of brick is not of so much importance as some of the other branches of the industry, as we have already mentioned, for the reason that by using any reasonable amount of care a brick that has been well moulded, and then allowed to dry to the proper consistence, must, of course, come from the re-press in good form, as the pressing of a pressed brick is more of a mechanical operation, and can be done with very little trouble by making use of the many improvements that have been made in the hand presses that are used for that purpose.

BURNING PRESSED BRICK.

"When we come to the final and most important part of manufacture, which is when the properly-dried and pressed brick go to the kiln to be burnt, that is where a brick-maker, and especially one engaged in the manufacture of pressed brick, has most of his trouble to overcome before he can make his business a success.

"The burning of clay after it has been made into any of the different kinds of articles for which it is now used, either in the form of any kind of brick or terra-cotta, crockery or tile, has always been a matter of great study and care.

"The manufacturer who is compelled to depend on the firing of clays before he can make a final success of his goods, will always have something more to learn, no matter how long he may have been engaged in the business.

"A successful manufacturer of pressed brick after he has taken into consideration all the benefits he may have received during the last twenty or thirty years from the improvements in machinery for the making or re-pressing of the brick, or the preparing and tempering of the clay, and after summing up the advantages he has gained by these, he will still claim that he has made more money and met with more substantial success to his business by careful study and improvements in the burning of the brick than he could make by all the other improvements combined. If a careful record could be obtained of what has caused the different failures in brickmaking, about four-fifths of such failures we think could be truthfully attributed to improper burning.

"We have mentioned these facts in regard to the burning of the pressed brick for the reason that we think it is the all-important question, and also that the matter may be fully discussed here, so that we can all have the benefits of the views of the different members of the Association on this subject.

"The reason why the proper burning of the brick is of vital importance in the business is that we have, before the brick reaches the kiln, expended upon it a very large proportion of the actual cost of its production, and notwithstanding all these expenses, the brick has no market value until it is burned. In fact, the green pressed brick has no more commercial value up to the time it reaches the kiln than the raw materials have while they are in the ground. You can therefore see by taking this view of it that the place for press brick manufacturers to make a sure success of their business is at the kiln.

"And I think, gentlemen, that if any one of you has a friend who contemplates starting in the brick business, and he should come to you for advice as to what kind of a machine is the best for a pressed brick manufacturer to make money with in the business, I think you will always be safe by simply answering 'the kiln.'

SETTING THE BRICK.

"The setting or placing of the brick in the kiln is a part of the work that we must depend on to a great extent to have the pressed brick well burnt.

"The idea which has been gaining ground for some years that brick cannot be set in the kiln too high or the kiln too large, we think is a mistake. Of course we speak now of the old method of burning brick in regular old-fashioned kilns, or what are termed the Dutch kiln. There are, as you all well know, many other kinds of patent kilns that have been tried and are still in use in many parts of the country; of these we cannot speak, as we have had no experience with them; therefore, our ideas of them either one way or the other would be of no particular value to any of you.

"But as to the setting of the brick in the open-top or Dutch kilns, we think that for burning of pressed brick a kiln should not be set over 36 to 38 courses high in all, that is from the bottom to the top of the kiln, including all the common brick in the kiln as well as the pressed brick. This, we think, is about as high as they should be set to burn economically and with safety to the pressed brick. Our reasons for this are that we think the quicker we can get the heat to the top of the kiln the better, as that is the part of course that is farthest from the fire, and the hardest, as a rule, to reach. We think for the same reason that the brick should be set very open at the bottom and throughout the body of the kiln until they reach within four or five courses of the top, and then placed closer so as to hold the heat when it reaches that point.

"As to the time required to burn a kiln of pressed brick

properly, it will of course depend somewhat on the kind of materials that are used in their manufacture, that is, as we have stated before, the materials used in making pressed brick differ very much, and some clays will take longer to burn into brick than others, but we do think that all brick are the better by being burnt just as quick as the nature of the clay will allow them to be fired

"Some persons may think that this is a strange doctrine to advocate in brick burning, as we well know that almost all of the theories that have ever been advanced on this point have been to the effect that the more time you consume in burning brick the better the brick will be. My reasons for taking the opposite view of this theory is that we think there is a certain amount of life (as we might term it for want of a better name) contained in the brick during the time it goes through the process of heating, which we think should be taken advantage of and used as a part of the burning process. As an example, we will call your attention to the re-burning of brick. There are many of you no doubt that have had occasion to re-burn brick the second time, for the reason of their having been burnt too soft at the first firing. We know that this has been done very often, not only by setting parts of a kiln with them, but we have seen whole kilns of salmon brick re-fired the second time; and you will find that when brick are brought in contact with intense heat the second time that the fire does not act as readily upon them as it did the first time, and while they may be burnt hard enough at the second firing, they certainly are not as good as the brick that are burnt to the right degree of hardness from a green state and at one burning.

"Hence, we claim that when we consume more time than is actually necessary to burn a kiln of brick, that the kiln becomes, to a great extent, somewhat in the nature of a brick that has come in contact with the fire a second time, or, in other words, you simmer away and destroy all the life which a brick has for fire before you commence to burn it, which not only adds to the expense of burning, but makes the brick of less market value.

"As to our own experience in the matter of burning brick, we will say that the brick-makers of Trenton have made that part of the business a study, and with some success, as some of you that are among us here to-day can testify, as we have had the pleasure of a personal visit from some few of you now present, and we shall be pleased at any time in the future to show more of you how pressed brick are burnt in Trenton, N. J.

"There is one circumstance connected with the brick business in Trenton which has compelled the manufacturer to make a careful study of burning brick, and that is, as before stated, the large percentage of pressed brick that are produced there to the amount of common brick made. As we all well know that good pressed brick cannot be burnt in all parts of an ordinary kiln, and when a manufacturer comes to making about sixty per cent. of all his production into pressed brick he is compelled to set a larger proportion of them into each kiln than it has been the general rule to do. So you will see that the proper burning of the brick is a very important matter to a Trenton manufacturer, for the reason that he has been to an extra expense in the manufacture of a very large proportion of his brick before burning.

"Brick-makers in Trenton all use the same kind of kilns, which are the ordinary coal kilns, with the grates running the full width of the kilns. The arches of the kiln are made stationary, instead of forming them with green brick each time the kiln is set. This is done more to save making so many common brick to form the arches with, than for any other purpose.

"The time occupied in burning a kiln in Trenton is about four days and three nights, or eighty-four hours in all. This includes the full time for firing, from the time the match is applied until the kiln is closed up and finished, and we think there are more kilns that are burnt there in a less time than we have stated than there are that over-run the time specified. The brick are all burnt with anthracite coal, no other kind of coal being used.

"We have kept a record in our yard for several years of the

cost of the fuel for burning our brick, and we have here a a statement covering seven years, which we will read to you, and you can then compare it with others that may be made here, as the matter of fuel for burning brick is a very important question, and we want to have all the light thrown on the subject that we can obtain.

COST OF FUEL.

"1881, number of brick burnt per ton of coal, 4,113; cost of fuel per 1,000 brick, $1.03; price of coal per ton delivered, $4.25.

"1882, number of brick burnt per ton of coal, 4,280; cost of fuel per 1,000 brick, $.97; price of coal per ton delivered, $4.15.

"1883, number of brick burnt per ton of coal, 4,274; cost of fuel per 1,000 brick, $.97; price of coal per ton delivered, $4.15.

"1884, number of brick burnt per ton of coal, 4,551; cost of fuel per 1,000 brick, $.91; price of coal per ton delivered, $4.15.

"1885, number of brick burnt per ton of coal, 4,530; cost of fuel per 1,000 brick, $.86; price of coal per ton delivered, $3.90.

"1889, number of brick burnt per ton of coal, 4,632; cost of fuel per 1,000 brick, $.89; price of coal per ton delivered, $4.25.

"1890, number of brick burnt per ton of coal, 4,267; cost of fuel per 1,000 brick, $.97; price of coal per ton delivered, $4.15.

"Making the average cost for seven years for fuel to burn 1,000 brick 94 6-10 cents per 1,000. And the average number of brick burnt with one ton of coal for seven years 4,378."

The following is from a paper read by Mr. C. W. Raymond, of Dayton, Ohio, before the Ohio Brick, Tile and Drainage Association, held in the city of Columbus, Ohio, February 25, 1891. The paper is entitled "Pressed and Ornamental Brick."

"I strenuously advocate the advisability of having certain days on which to 'strike out' brick for re-pressing. Special care can better be given to the preparation of the clay; the machinery, belting, molds, presses, etc., can be cleansed and oiled for the occasion; dry clay or hard particles removed from the machine or pug mill; the drying floor, pallets and racks be swept and having removed all dirt and dust from them; the

brick machine can be run at a slower speed to admit of time being taken to give the best results in handling; in fact, the rush and hurry incident upon making large numbers of common brick can be avoided. Again, in striking out brick for re-pressing it is necessary that an extra amount of clay should be contained in them. First, to compensate for condensation given them by pressure. Second, pressed brick when laid in the wall require a much smaller mortar joint than common ones; hence to bond with them properly they must be thicker, therefore larger molds are required. These and other reasons present themselves why it is advantageous to have stated days or times for this work.

"I would not advise my friends to attempt to make pressed brick without satisfying themselves that their material is suitable, either in itself or susceptible of advantageous combination. This should be determined by an actual test by a practical burner. A chemical analysis is of inestimable value in determining the presence of alkalies or other impurities which cause so much unsightly efflorescence in many of our fine fronts. The novice, however, need not be discouraged if his first trial does not 'pan out.' If it does not indicate that he has made a 'rich find,' additional experimenting, combination or chemical treatment may later on develop the fact that he has struck 'pay dirt.'

"The manner of preparing the clay and striking out the brick for making pressed brick is identical with that of making common brick, except, perhaps, the precautionary measures that are taken to insure the very best results. It seems unnecessary for me to describe a process so well known to you all. Weathering is usually advisable. It is a great help in the tempering or pugging of the clay, as the assimilation caused thereby lightens the work on the machinery and produces a thorough mixture of the strata.

"It is important first of all that the clay be free from stones, roots, and all foreign substances. Judicious work of the pit-men in 'weeding' out the largest of these at the clay-bank is

commendable. Frequent stoppages of the machinery are avoided, and its liability to breakage reduced to a minimum.

"If stones abound in any quantity they should be separated from the clay by a roller crusher, or if they be not large and of a limestone formation, a disintegrator or pulverizer to reduce them will answer. In the latter contingency the crushed stones form an integral part of the clay and are worked up with it. Experience alone can demonstrate whether they deteriorate its quality or are otherwise objectionable.

"The pugging process which follows is one of importance, as upon its thoroughness depends largely the uniformity of your material. A pug-mill, in addition to the one which usually forms part of the machine, relieves the latter of excessive strain and better prepares the clay for all future work upon it; in fact, by its use the clay is thoroughly prepared before reaching the machine, whose only remaining duty is to strike out the brick.

"In sanding the moulds for use with the machine, a fine sand giving a rich, red color, is required. Where this is not obtainable, good results can be had by using moulding sand, or the dust from the rattle, procurable in any foundry. Sieve through a very fine sieve, not less than No. 60.

"Tempering clay by a wheel and moulding by hand is still followed in many localities. Results from this method, although slow, have always proven satisfactory and profitable.

"What machine, if any, is best adapted for re-pressed brick? I have seen very excellent brick made on all machines, hence I do not advocate any kind of machine or any special mode of manufacture. The machine is but the agent for putting the gluts into shape; for producing the necessary amount of clay in each. This, I claim, can be done successfully by any of the good machines now on the market, other conditions being favorable. As to the machine best adapted to the manipulation of any special clay, it is a question to be determined only by actual experience or trial with it.

"The re-press, although a small machine, plays a no less important part in the production of fine brick than larger and

more expensive ones. The press should at all times be kept clean and its working parts oiled. I commend the method in use in some of our yards which requires the pressman to clean and oil the press thoroughly at the completion of each day's work.

"The dies of the press should be frequently dressed or re-lined, and the plungers packed out to fit snugly therein; perfect brick may not be expected from an imperfectly constructed or partly worn die, as each brick will take on all the imperfections of the press die.

"I am frequently asked how much pressure is required to re-press a brick. I have never yet attempted to answer this question, and will not do so here, but will say: When the edges and corners of the brick are perfectly developed, the end sought by re-pressing is attained. Multiplied tons of pressure will not do more.

"A skilled workman who can exercise judgment in handling and working the press should operate it. When the press is in operation the die should be wiped off with an oiled rag or brush after each brick is pressed, or as often as required to prevent adhesion of the brick to the die. An oil suitable for this purpose is composed of coal oil one part and lard oil three parts, or coal oil and engine oil in the same proportion, or coal oil and rancid butter; the latter being warm and mixed makes an excellent lubricant.

"The little paddles by which the brick are removed from the die after pressing must present a smooth and even surface to the brick, and should be rubbed off occasionally to remove accumulations of clay, or redressed when their surfaces become uneven by wear.

"The drying sheds I consider as necessary to the production of good pressed brick, as the press and other fixtures. By their use the sun is excluded, the air currents are controlled, and you are better able to produce brick of an even temper throughout, without which good results in re-pressing are impossible. Brick dried in the sun or out of doors, dry

hastily and unevenly; their inner portions remain soft and mushy while their surfaces are crusty, and their corners and edges dried prematurely; thus rendering them unfit for the re-press. The brick must dry slowly and regularly. This result can be obtained by the drying shed.

"The drying shed can be arranged with racks similar to an outdoor rack for drying. They should be built wide enough apart to allow the trucks and presses to be wheeled between them, and not so high but that the pallets of brick can be removed from the top shelves easily. Boards running lengthwise with the shed can be hinged, forming an easy manner of regulating the air currents. A moderate degree of artificial heat can be introduced to advantage.

"When the gluts are in a proper condition for re-pressing, they are taken from the racks, picked up carefully one by one, and their faces smoothed over by hand or rubbed lightly with a soft brush. They are then laid on the plunger of the re-press and subjected to uniform and gentle (not over) pressure. After their expulsion from the press die they are carefully picked up by an off-bearer between two thin paddles and replaced again in their position on the racks. Frequently, however, they are hacked one above another until four or five high and allowed to dry in this manner, or again they are removed on trucks to a drying floor where they are allowed to remain unmolested until ready for the kiln. In any event it is advisable to handle the brick after pressing as little as possible until they become dry.

"A most significant step in the production of fine front brick is setting. This should be done by competent men who will exercise judgment and care that the importance of the work demands. Setting as done by the Royal Brick Company, of Bridgeport, Ohio, is as follows: (I mention this company as one of several with whose manner of working I am familiar, and who have been able to attain a great degree of proficiency in their special line.)

"They use, I believe, an up-draft kiln. After the arches are

turned the courses are leveled the entire width of the kiln; so much importance do they attach to this that a spirit level is used for the purpose. The brick must be set, not only perfectly level, but plumb. The settling heat, therefore, if the burning is uniform, is more likely to bring all down regularly and even, which to a great extent will prevent sliding, warping or twisting. Their brick are set one face exactly above another, neither projecting at the ends or sides. The courses do not extend to the walls of the kiln, but are separated therefrom by several lengths of common brick.

"They commence to set pressed brick as near above the top of the arches as possible, and extend about fifteen to eighteen courses high in a kiln of forty to forty-five high including all. This they think is as many as can be burned profitably.

"I would not advocate either the setting of the entire kiln so high or the placing of so large a number of courses of pressed brick therein. In many cases it would result disastrously, giving an unusual per cent. of salmon or under colored brick by reason of setting too high on the one hand, or hard or over-colored brick by proximity to the arches on the other. This question, however, can only be determined in each case by actual results of burning.

"Brick should be thoroughly dry before setting. The courses should be set open at the bottom and closer as they near the top of the kiln, and should be burned as quickly as the nature of your clay will permit. These, I believe, are points about which no controversy exists.

"A matter of serious concern to the manufacturer, and one which sustains a greater relation to profit and loss, to success or failure, is burning. Whatever importance may be attached to this in the production of common brick, it is doubly so in that of pressed and ornamental.

"When the brick have arrived at that state of their production where they are ready to be burned, all labor has been expended upon them. A kiln of brick ready to fire frequently represents from $1,200 to $1,500 invested capital. It matters

not what expenditure of money has been made in purchasing the most improved machinery and devices to insure the very highest results in manipulating your clay, it matters not how thoroughly your clay may have been prepared, or how carefully or deftly your brick may have been handled from the machine to the racks, from the racks to the press, from the press to the drying floor, and from the drying floor to the kiln, all is lost unless the burning is successful.

"Does it not behoove us then to use the most improved systems of burning? Should not the highest skill of the burner's art—for it is an art—be called into requisition?

"The kind of fuel required and amount thereof consumed, the time required in burning, etc., are largely questions to be determined by experience, and depend upon the chemical properties and peculiarities of your clay, and should command your best study and thought. I can find no fixed rule applicable to all cases. The main point in burning pressed brick is to obtain a uniform color, which can be done only by uniformity of heat and an even combustion in all parts of the kiln. While these conditions should exist in all burns, they are especially essential to the successful production of fine pressed brick.

"When opening the kiln remove the common brick down to the top course of the pressed brick, sweep or brush these courses carefully, remove the press brick two at a time, toss in pairs and lay on a spring barrow. Use lath between the layers, and load about forty brick to the barrow. Great care must be exercised in handling the brick to prevent chipping or spalling. The faces must not come in contact one with the other, or an ugly scratch or mark will be the result.

"A dry, roomy and light stock shed should be arranged with ten or twelve stalls or apartments for the various shades of brick. To this shed the brick are wheeled, where they are taken charge of by the sorter, one whose duty it is to arrange them according to their various colors and shades. A man with clear perception, a keen eye, and excellent judgment,

should fill this important office. If not graded by an artistic eye according to their delicate shades, they would but present a spotted and unsightly appearance to the beholder when shown in comparison in the walls of a fine building.

"This, I believe, completes a description of the machinery, appurtenances and methods of making and handling successfully re-pressed brick. I might have entered more largely into details, but these are well known to you all. The points I have suggested are general, and will apply to any system, and if adhered to, cannot fail to be of value.

"In making a brick of fine quality for front, few realize the importance of properly preserving the faces of the brick from contamination or abrasion. It is a prevalent but fallacious opinion that anything will make a pressed brick, that the press will remove the imperfections, square the brick, and make an artistic and beautiful piece of work from an ill-shaped glut of clay. Such is not the case. Abrasions, finger marks, paddle marks, etc., once given to the face of the brick cannot be removed by the press; in fact, it is my conviction, based upon observation, that the higher finish and beauty the surfaces of your pressed brick are susceptible of, the more sensitive they are to these defects.

"Another point to which I would direct your attention is the growing disposition to produce large numbers of pressed brick per day. Many of our manufacturers require from 4,000 to 5,000 brick to be re-pressed per day by two men, using one hand press. Excessive quantities of pressed brick can only be produced at the expense of that more desirable property, quality.

"In Philadelphia, the Mecca of the pressed brick industry, but 1,500 to 1,800 brick are produced per day, each glut being struck out singly and by hand in a steel or brass mould. While this manner of working seems to the average Westerner somewhat primitive, yet the world-wide reputation and high market value of Philadelphia brick would indicate that the standard of excellence which they have attained is due to their fine quality,

which can only be had by the exercise of great care and patience in their production.

"I find I have omitted all reference to the manufacture of ornamental brick, and the great improvements which have been made of recent years for their manufacture, whereby from one to two thousand elaborate and beautiful designs are made per day, where formerly but as many hundred were produced. Nor have I referred to the advent of the power press, whose coming promises to revolutionize old and slower methods of re-pressing brick.

"A few years ago the manufacturer who would have proposed to handle by automatic mechanism so delicate a form as a soft brick would have been voted, putting it mildly, peculiar. Now we find the power press used in many of our large yards, working with almost marvelous results. However, as they, as well as manners and forms of working in connection therewith, are yet subjects of study and development, I will content myself with this brief reference.

"An aphorism in vogue among chemists says, 'In medicine quality is of first importance.' The same may be aptly applied to pressed brick. Quality is of first importance. It is from this they obtain their high market value. Without the care and time necessary to give your pressed brick their well defined lines, their smooth velvety surfaces, their symmetrical proportion, in fact, without a desire to attain the IDEAL, they are frequently of little more value than the common ones, and their enhanced worth will not justify the expenditure of time and money necessary for their production.

"A story well known by you all is told of an old darkey who was called to the bedside of his dying master, and informed that he might have any three wishes gratified that he might name. The old fellow was nonplussed at such a beneficent and unexpected offer, but when pressed for an answer, replied, 'Well, Massa, I want first, all the whiskey I can drink. I want second, all the clothes me and the old woman can wear,' and, rather doubting the scope of his first request, said, 'well, Massa,

if it makes no difference to you, I'll take a little more whiskey.' Applying the logic of this story to the subject in hand, if asked the prerequisite to the successful production of fine pressed brick, I would say CARE, and if asked the next in importance, I would say A LITTLE MORE CARE."

ORNAMENTAL BRICK.

Ornamental brick are usually made in the same manner as fine pressed brick; the quantities produced for a day's work are less, but vary with the size and complications of the designs.

In the year 1884 the Perfection Press was invented and patented by Mr. C. W. Raymond, of Dayton, O., a novel and simple machine with great power, in construction deviating from the similarity between those of its class then existing.

Mr. Raymond had made the wants of the brick-maker a study for years, having previously invented several useful and valuable improvements for their use. The Perfection Press was largely the result of his experience and investigation.

The press, which is illustrated in Fig. 69, is constructed entirely of iron and steel, the finest material only being used. For the dies, which require hardness and a high finish, a special grade of steel is manufactured. All parts are capable of adjustment. The entire work of pressing the brick and removing it from the die is accomplished with one motion of the lever; this important point facilitates the work and allows the brick to be handled much more rapidly than where 2 or 3 levers are employed.

Any size or shape mould can be used upon one press, hence a great variety of work can be done with this press, such as red brick, fire brick, paving blocks, roofing tile, etc.

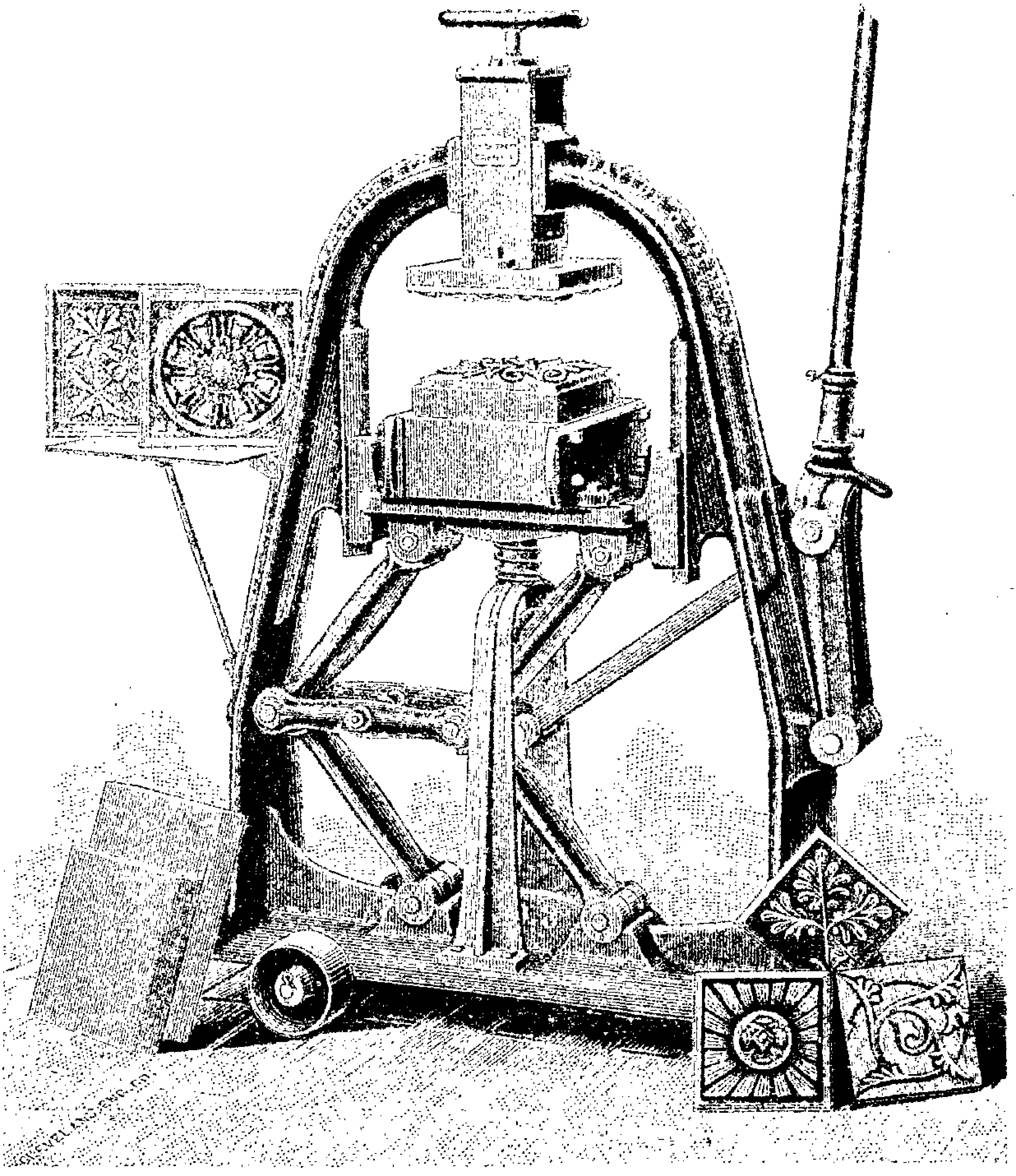
It can be adjusted to press any brick of any thickness by the adjustable platen at the top.

Its great power is also a feature rendering it valuable on the heavier grades of work.

The special feature of the press, however, and one which has worked a great change in the manner of making ornamental

brick and terra-cotta, is its adaptation to that work. The ornament is used upon the top plunger, which after pressing

FIG. 69.



RAYMOND'S PERFECTION PRESS.

the brick entirely lifts itself from it. All annoyance of loose plates in the bottom of the press dies required by other presses

is avoided, and the finest designs are produced almost as readily as common brick.

The ornamental plates are made in brass from designs furnished by the manufacturer of the press or submitted by the purchaser, and can be used upon each press in endless variety.

It has been demonstrated that the best results in ornamental work can be obtained where great pressure is employed, thereby solidifying the block, imparting to the surface that lustrous, velvety appearance so much sought for, pressing the most obscure parts into prominence, and giving to each block uniformity of size and figure absolutely essential to architectural effect.

Mr. Raymond, by his patented Perfection Press and system of working soft clay into ornamental and terra-cotta designs, has reduced a heretofore complicated process to exactness and simplicity, opened up an inexpensive and exhaustless field of manufacture to the brick-maker, and made it possible for artistic results to be obtained by those of ordinary means and comparatively little experience.

In the manufacture of ornamental brick and tiles, by the use of a re-press, the "stiff-mud process" can be successfully employed for the following reasons: The clay being stiff enough to re-press as soon as run into the right form and size—either 4x8, 8x8, 10x10, 12x12, or any other desired size—the labor of handling is avoided. The clay, having no sand on its surface, takes a clean, sharp, well-defined impression from the matrix.

The following is a brief description of the method of the manufacture of ornamental brick and tiles by the "stiff-mud process:"

When the clay blank or "glut" is in the right condition to re-press, it is dusted on the face side which is to receive the impression, and this side is placed upon the matrix, which is a thin plate with the reverse of the pattern which you desire upon one side. This matrix or mould is in the bottom of the press-box, in some presses. Manufacturers have various appli-

ances for making ornamental work. With some the plate is placed in the bottom of the press, and others have the plate on top of the brick while pressing.

In the first case the brick is lifted off from the plate after pressing, and in the other the plate is removed before the pressed brick is lifted entirely from the mould.

A third method is to have the matrix fastened to the cap, top-plate, or follower, as the case may be, according to the kind of press you are using, and when the cap is lifted off, the matrix is lifted with it, and then the brick is lifted from the press without the danger of distortion, such as the other methods present, in attempting to remove the plate from the brick. Each of these processes has its respective advantages, and the manufacturer must use such a one as to him seems best.

To manufacture to the best advantage, three presses should be used, one for large tile, one for brick, and one for edge-work, but one press may be made to answer by changing the press-box and follower plates.

Various substances are employed to prevent the matrix adhering to the clay. Oil is generally used for this purpose, but in designs having great relief or depressions it is sometimes almost impossible to remove the matrix from the ware without injury; others use dust of some kind—very fine sand—which will burn a good color; pulverized coal, charcoal, etc., are also used.

Brick-dust passed through a bolting cloth is the very best thing that can be utilized—burns, of course, the same color as the clay, and produces a rich, velvety surface, and the brick never stick.

When the ornament required is very bold, it is best to re-press twice.

After the first pressing, which should not be very hard, the brick is dusted.

When it has shrunk just enough to drop easily into the mould box, the superfluous dust is blown off, either by a

bellows or lung power, and then pressed the second time firmly. The subsequent treatment consists in carefully removing any superfluous clay from the edges, a little hand-rubbing, and careful drying and burning.

The main thing to insure success in ornamental work, either with mouldings or pressed work, is thorough preparation of the clay.

It should have sand or "grog" enough in it to prevent undue shrinkage, or liability to crack, in drying or burning. For the higher classes of ware, clay that had been once burned and pulverized should be used to the extent of about 25 per cent.

The Northwestern Terra-Cotta Works, of Chicago, Ill., buy all the bats from the Anderson Pressed-Brick Company that they have to spare, and grind them up by a slow-motion large-diameter crusher. One crusher crushes the bats to the size of a hickory-nut. They then pass through another crusher, and everything is ground fine. The works named use crushed brick to the extent of 40 or 50 per cent. in some of their wares, and always with good results.

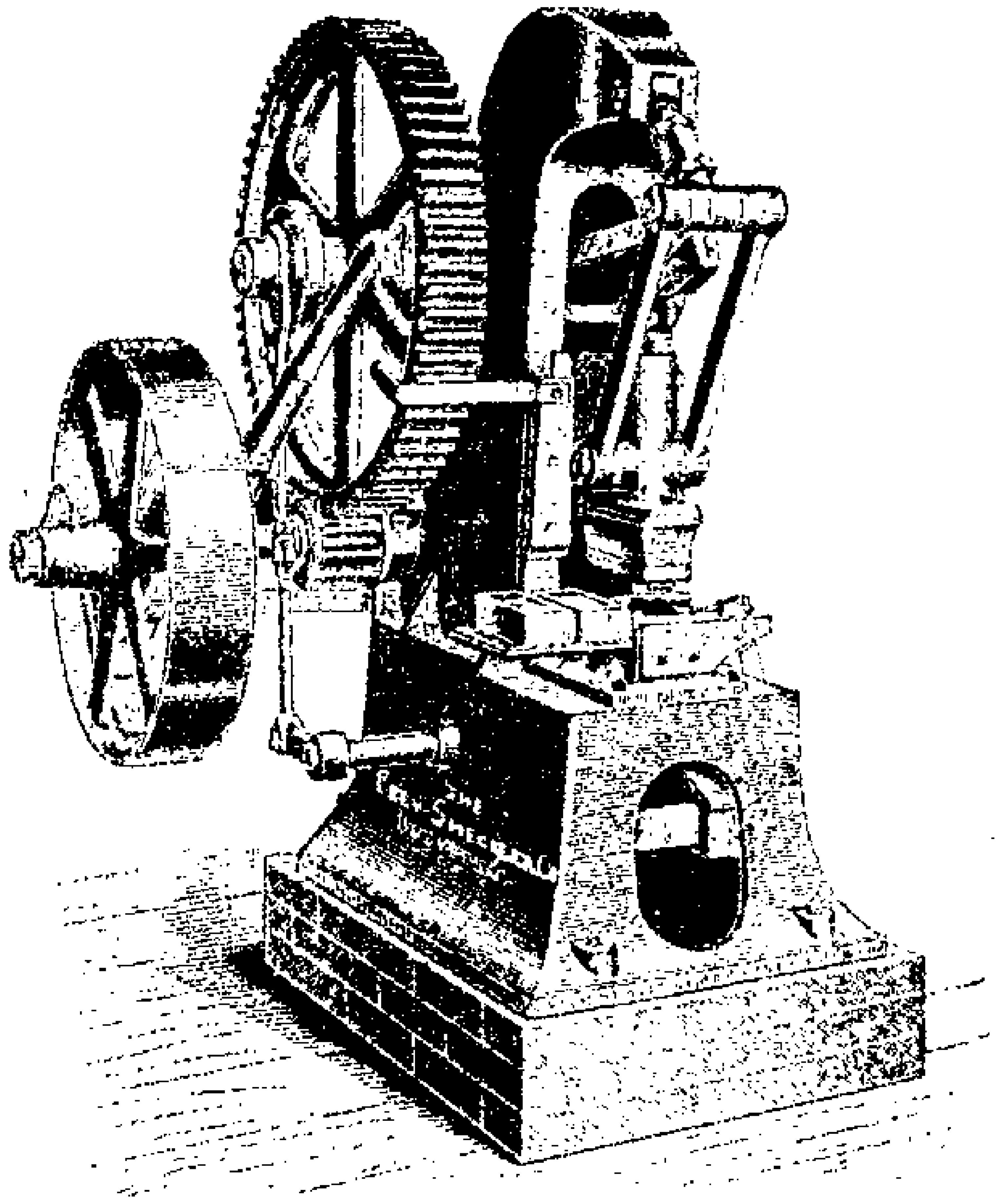
Mr. Batley, in speaking of the use of pulverized bricks, or "grog," for preventing the excessive shrinking of clay during the process of manufacture, said: "In South Wales we were engaged in making enameled glazed brick, fire-brick and sewer-pipes, and when we came to the question of anything over half an inch to three-fourths in thickness, it used to warp and crack all to pieces, and it soon put me to thinking what to do to prevent the clay from cracking; and while there engaged in making 24-inch sewer-pipe, I have had to use as much as 60 per cent. of 'grog,' and the clay is not in existence, as far as my experience goes, that cannot be prevented from cracking."

After the "grog," or pulverized brick, has been mixed with the green clay, the mixture should be allowed to remain for one week in the tempering pit after being wet, and as long after pugged the first time as possible, before being run into moulding or for pressed ware.

Success in ornamental brickmaking, as in all other manufacturing enterprises, is determined largely by attention to details.

Fig. 70 shows a front view of the Panel Re-press, which is manufactured by the Frey-Sheckler Co.

FIG. 70.

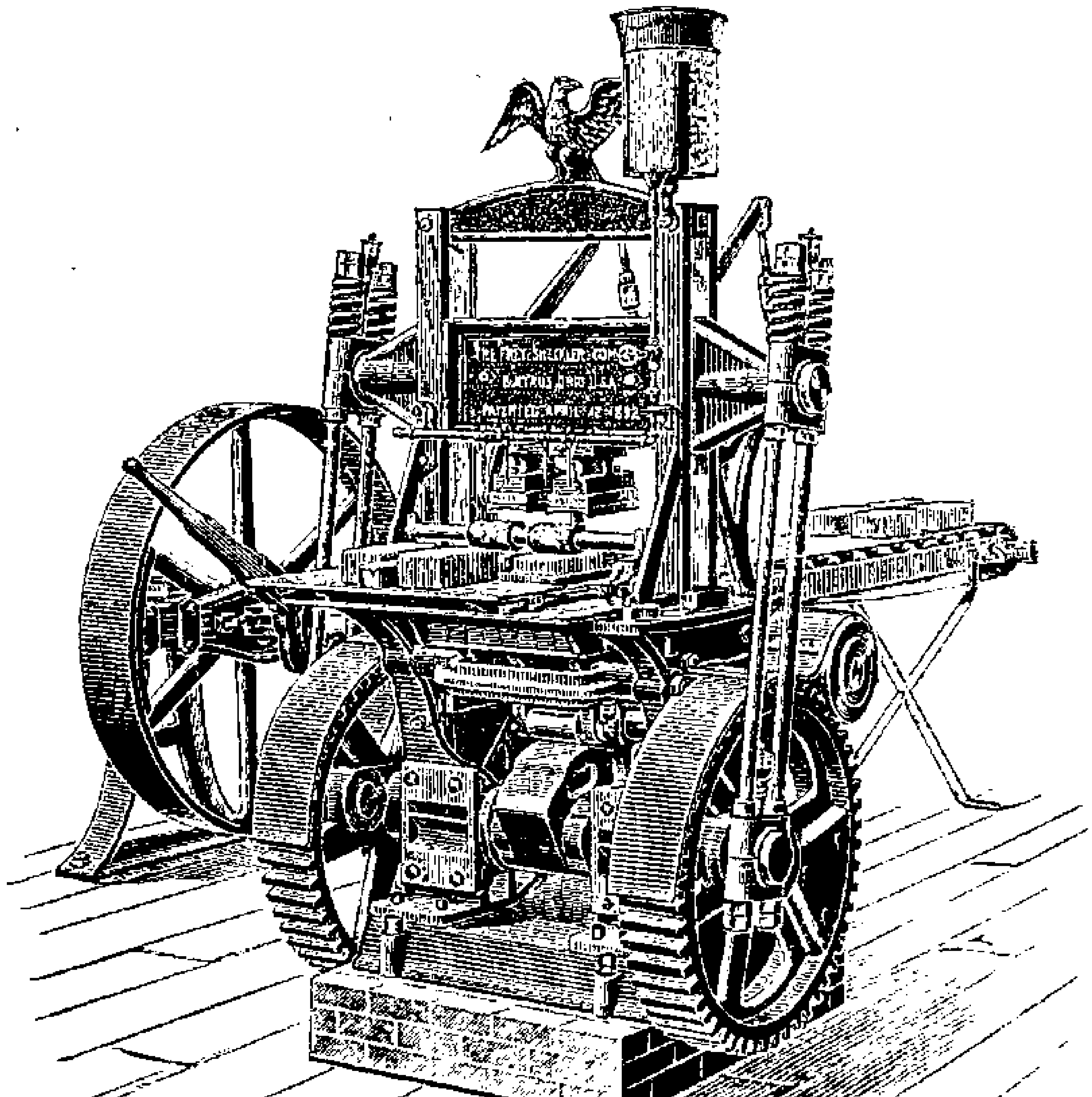


This was the first and is the only machine of its class manufactured in the United States. It is especially designed to meet the wants of brick manufacturers producing a high grade of brick for enameled glazing, where it is very essential to have all of the brick of an exact thickness. It is also adapted for pressed and ornamental brick when a fine finish of product is required. This machine is constructed on new and scientific principles, as will be seen by the illustration. The shafts are made of steel. The gears are extra heavy and of new design. The machine is mounted on an extra heavy cast-iron box bed. It is simple in construction, easily accessible, and no parts liable to get out of order. All of the gears and mechanical movements are so arranged as to be entirely free from clay, etc., so as to prevent wear. The feed and discharge of the brick in this machine is strictly auto-

matic. Machines of this class from abroad do not enjoy this ingenious mechanical device, but must be stopped at the pressing of each brick in order that the same may be removed from the mould. This machine is supplied with a friction-clutch pulley, so as to enable the operator to start or stop the machine at will. Capacity from 6,000 to 10,000 highly-finished brick per day; weight of machine 4,500 pounds.

Fig. 71 shows a front view of the Eagle Double Mould Re-

FIG. 71.



press, which is manufactured by the Frey–Sheckler Co. It is intended for re-pressing front brick, roadway paving brick, fire brick, etc., and has a capacity of 15,000 to 28,000 every ten hours.

CHAPTER IX.

KILNS.

TEMPORARY KILNS.

THE question of what method of burning to adopt or what class of kilns to employ is one which must be largely governed by local circumstances. If the works are not located near clay fields which promise to yield clay in sufficient quantities to warrant the erection of permanent kilns, then, of course, the only thing to be done is to use temporary kilns or "clamps."

Ordinarily the fuel in temporary brick-kilns or clamps is placed within the arches either directly upon the ground, when wood is used, or upon grates extending through the entire length of the arches. This mode of firing is objectionable, for the reason that it is commonly very difficult to regulate the fire so as to produce brick of uniform color and strength.

The kiln shown in Figs. 72, 73, 74, 75 and 76, which is that of Mr. Wm. H. Brush, of Buffalo, N. Y., is designed to remedy the difficulties and objections named.

FIG. 72.

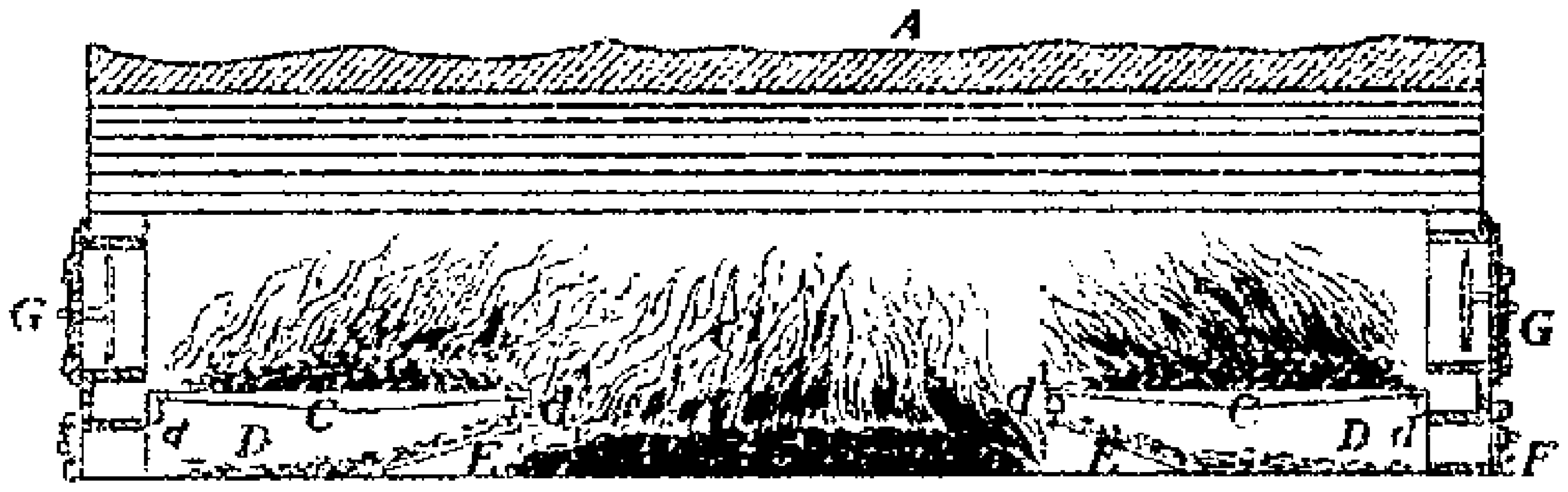
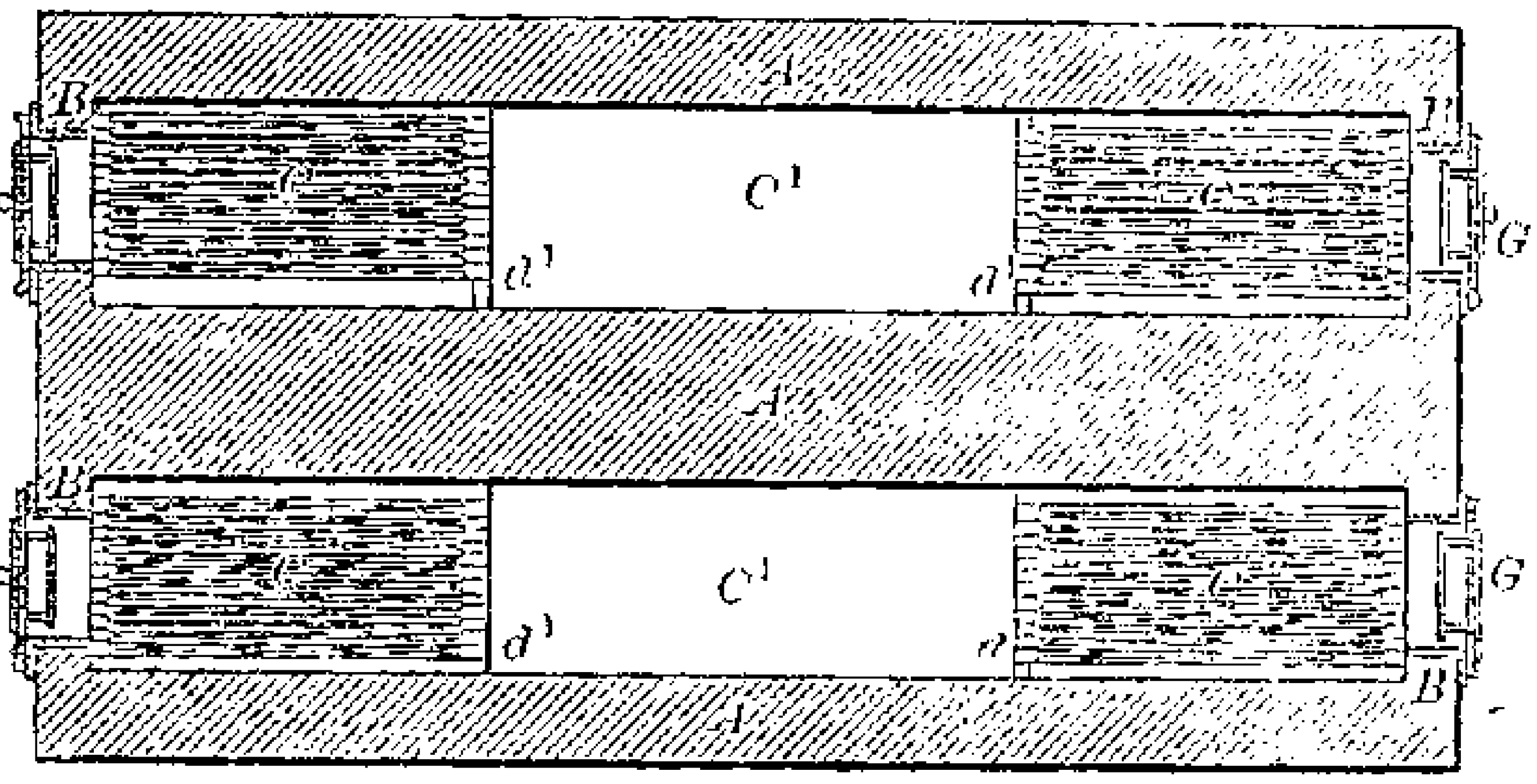


Fig. 72 is a sectional elevation, showing an arch of a brick-kiln provided with the Brush improvements. Fig. 73 is a plan view of two arches. Fig. 74 is a front view, showing one arch in front elevation, and one in cross-section. Fig. 75 is a rear view, and Fig. 76 a horizontal section of the fire-door.

A represents the arch of green brick set up in the usual manner. *B* are the frames of the fire-doors, arranged in the outer walls of each arch in the ordinary manner. *C* is a fire-grate, preferably about five feet in length, arranged within each arch, at each end thereof, as clearly shown in the drawing. The

FIG. 73.



grates *C* are supported upon bars $d\ d^1$ resting upon the brick of the ash-pit *D*, which latter is preferably composed of old or burned brick. *E* is an inclined plate or apron hinged or hung to the rear grate-bar d^1, as clearly represented in the drawings, and made of the same width as the ash-pit, so as to prevent the cold air in the ash-pit from entering the arch, except

FIG. 74.

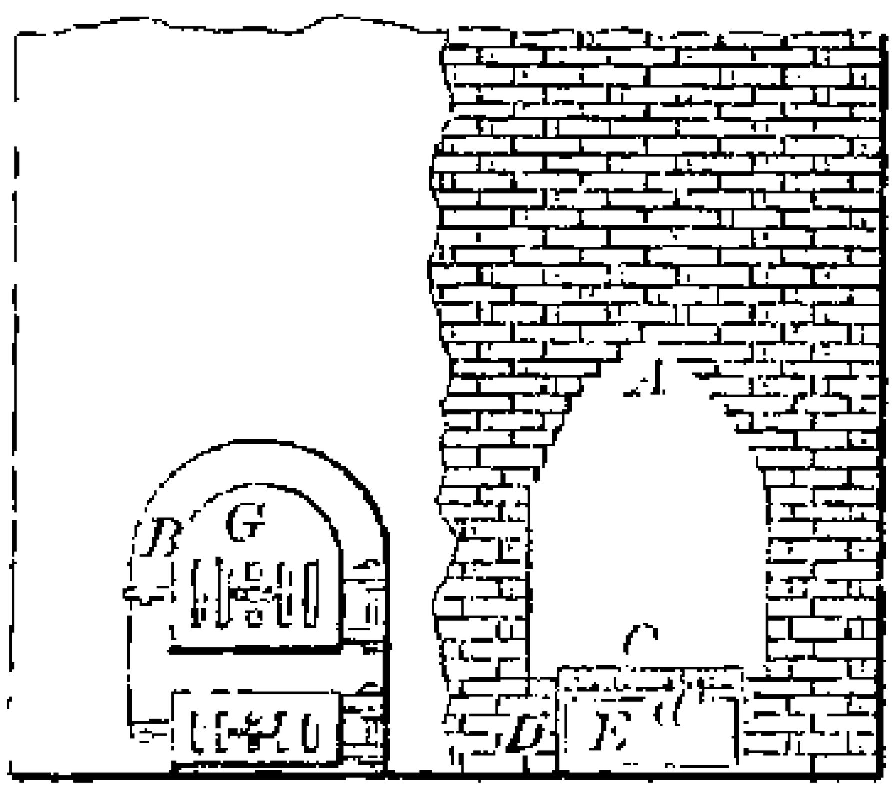


FIG. 75.

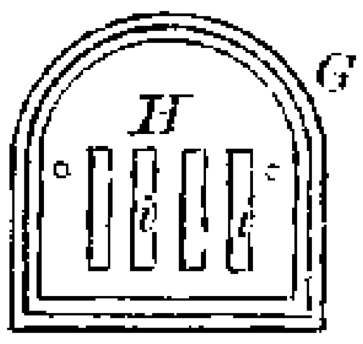


FIG. 76.

through the burning fuel upon the grate *C*. The aprons *E* incline toward the ash-pit door *F*, so as to cause the ashes and cinders dropping upon the aprons to slide forward toward the ash-pit door; and the hinging of the aprons to the grate-bars enables the front ends of the aprons to be raised, so as to per-

mit access to the fuel placed upon the ground between the grates *C C*.

G is the fire-door, hinged to the frame *B*, and provided with vertical slots or openings *g*, which are opened and closed by a sliding-plate g^1, in the manner of an ordinary register.

H is a protecting-plate, arranged on the inner side of the fire-door *G*, and connected thereto by stay-bolts *h* in the usual manner: *i* are vertical slots or openings, arranged in the plate *H* in such a manner that solid portions of plate *H* are opposite the openings *g* of the fire-door *G*, and the openings *i* opposite the solid portions of the fire-door. This construction of the protecting-plate *H* causes the air-currents entering through the openings *g* of the fire-door to impinge against the solid portion of the plate *H*, which, being kept at a very high temperature by the fire upon the grate, heats the air before it enters the arch, thereby preventing the brick from becoming checked.

The grates *C* may be charged with wood or coal, and the space C^1 between the grates is preferably charged with wood or coke. By admitting a strong air-current through the fire-doors *G*, the flame and hot gases are driven from the grates *C* toward the center of the kiln, and the combustion of the fuel between the grates is accelerated. Upon closing the damper in the fire-door *G*, the hot gases from the grates *C* rise perpendicularly through the arch, and the combustion of the fuel between the grates is retarded. Upon raising the ends of the aprons *E*, the ashes can be raked out from the space between the grates, and new fuel can be supplied thereto without interfering with the fuel upon them, while, by supporting the front ends of the aprons in a greater or less elevated position, the combustion of the fuel in the space between the grates can be regulated without affecting the combustion of the fuel upon the grates.

It is obvious from the foregoing description that these improvements, which are readily and cheaply applied to kilns of ordinary construction, give control over the fires in all parts of the arch, thereby enabling the brick to be burned to a more uniform color than in clamps as ordinarily constructed.

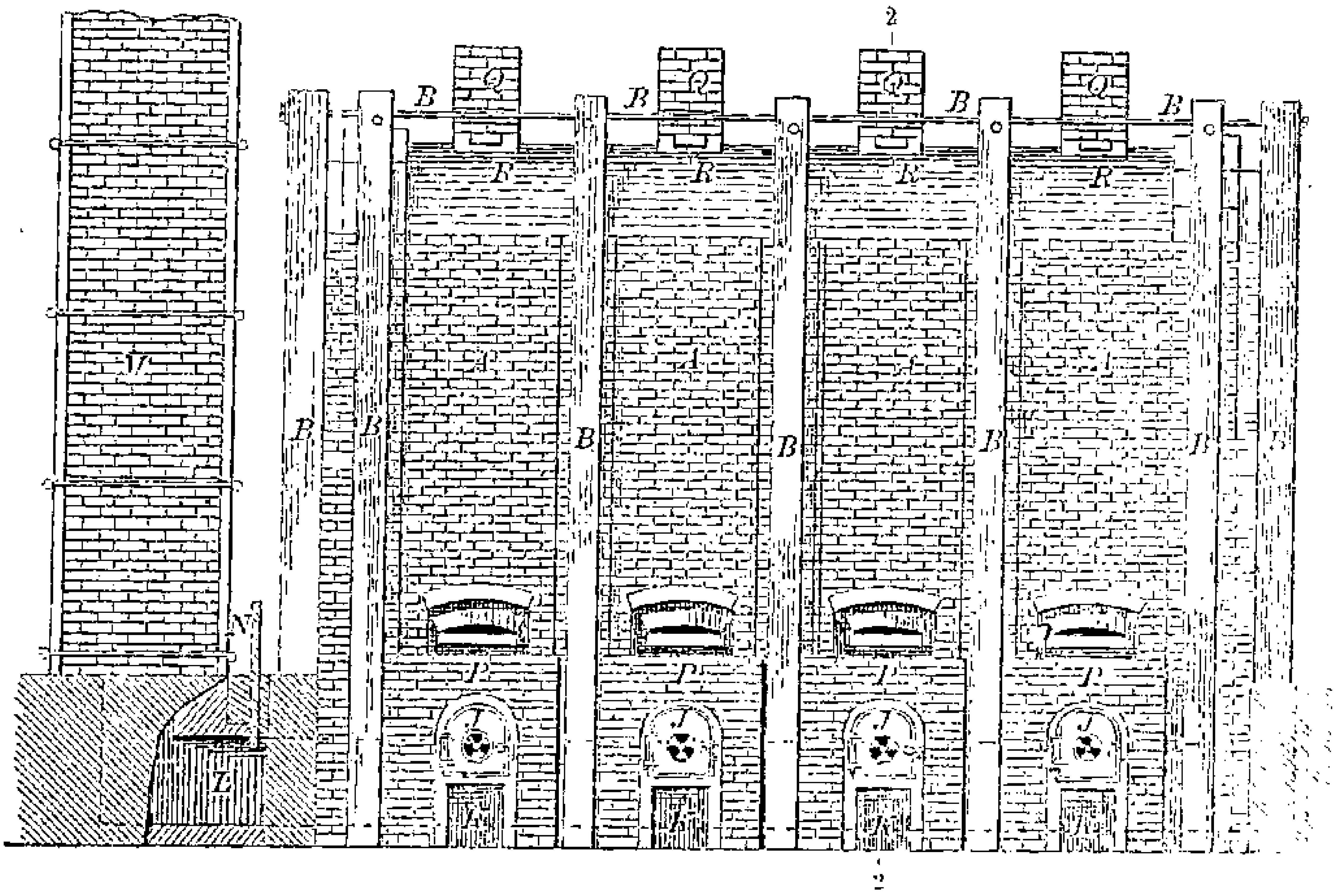
The entire fire-surface being arranged within the arch, the heat developed by the fuel is fully utilized, and loss from radiation, while not of course fully prevented, is to a great extent curtailed.

UP AND DOWN DRAFT KILNS.

Kilns for burning brick and tiles thoroughly and economically are often constructed with an up and down draft which connect with the same fire chamber and are usually provided with flues arranged beneath a perforated floor and which communicate with the main chimney and outlets on top of the kiln, the flues from the fire chamber being provided with suitable dampers.

The kiln shown in Fig. 77 is the invention of Mr. Willis N.

FIG. 77.



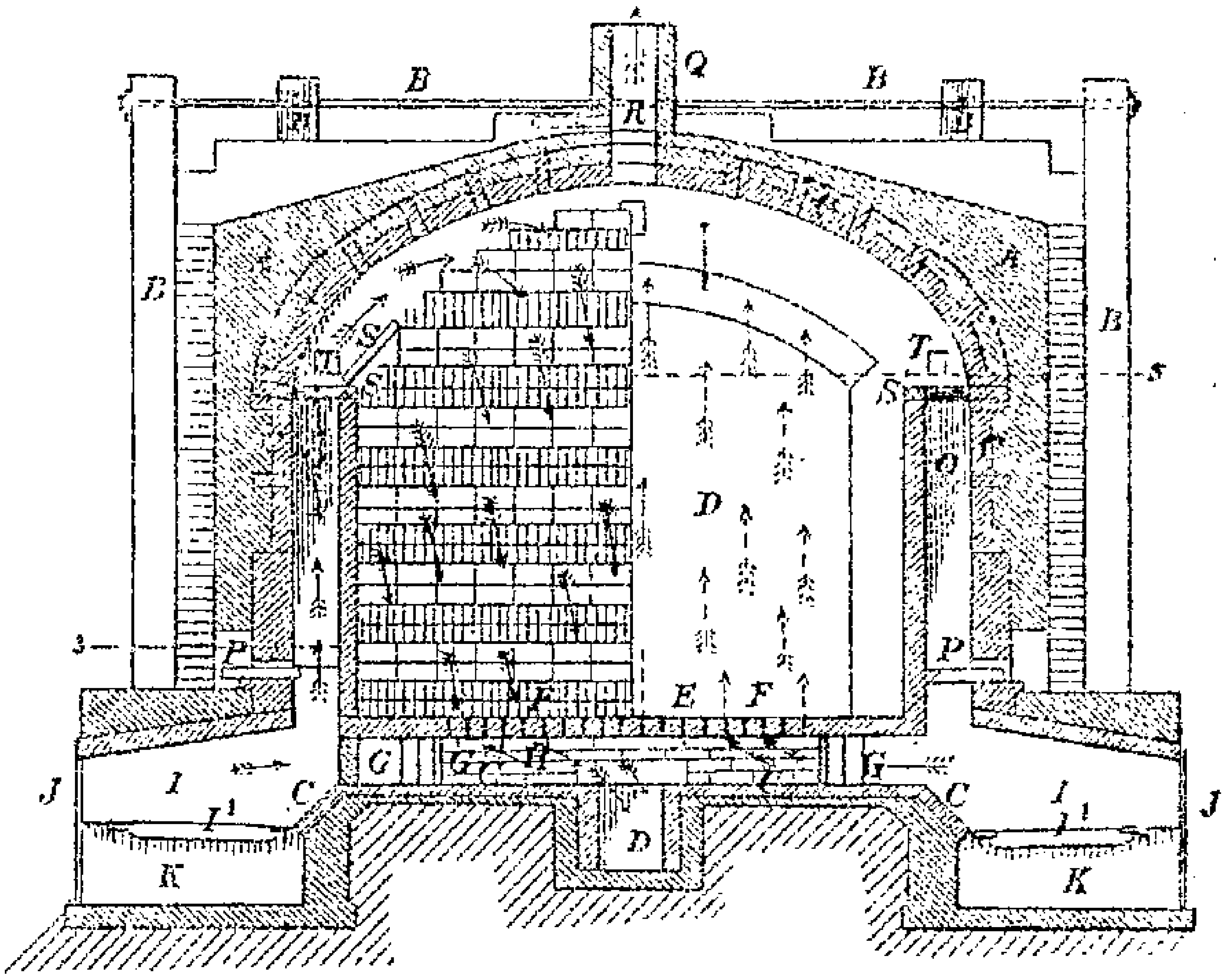
Graves, of the Hydraulic Brick Co., St. Louis, Mo., and it consists, first, in the arrangement of the flues beneath the floor of the kiln; and, secondly, in preventing the products of combustion taking the shortest course from the tops of the vertical flues to the flues beneath the floor.

Fig. 77 is the front elevation with a small portion of the escape-flue broken away. Fig. 78 is a vertical section taken on line 2 2, Fig. 77, showing one side of the kiln filled with brick,

and the other side empty. Fig. 79 is a horizontal section taken on line 3 3, Fig. 78, with part of the floor of the kiln broken away, to show the distributing-flues beneath.

A represents the outer walls of the kiln, strengthened by ties *B*, as usual, and having the customary lining *C*, of fire-clay.

FIG. 78.



D represents the kiln or brick-chamber, with a floor *E*, with passages *F*, forming a communication with flues beneath the floor. The floor proferably consists of tile made from fire-clay, supported on walls or ribs *G*, which form the main flue for each fire-chamber, or each set of fire-chambers where two series are used, as shown, and these main flues are subdivided by the intermediate wall *G*, which does not quite extend to the sides of the chamber, as shown in Fig. 79, thus forming small distributing-flues H H^1 H^2 H^3. Of these three intermediate walls, the outer ones have inturned ends H^4, so that as much heat is deflected into the two outer flues H H^3, as passes directly into the two central flues H^1 H^2. We have shown a series of fire-chambers *I*, at each side of the kiln as the preferred form; but one series only may be used.

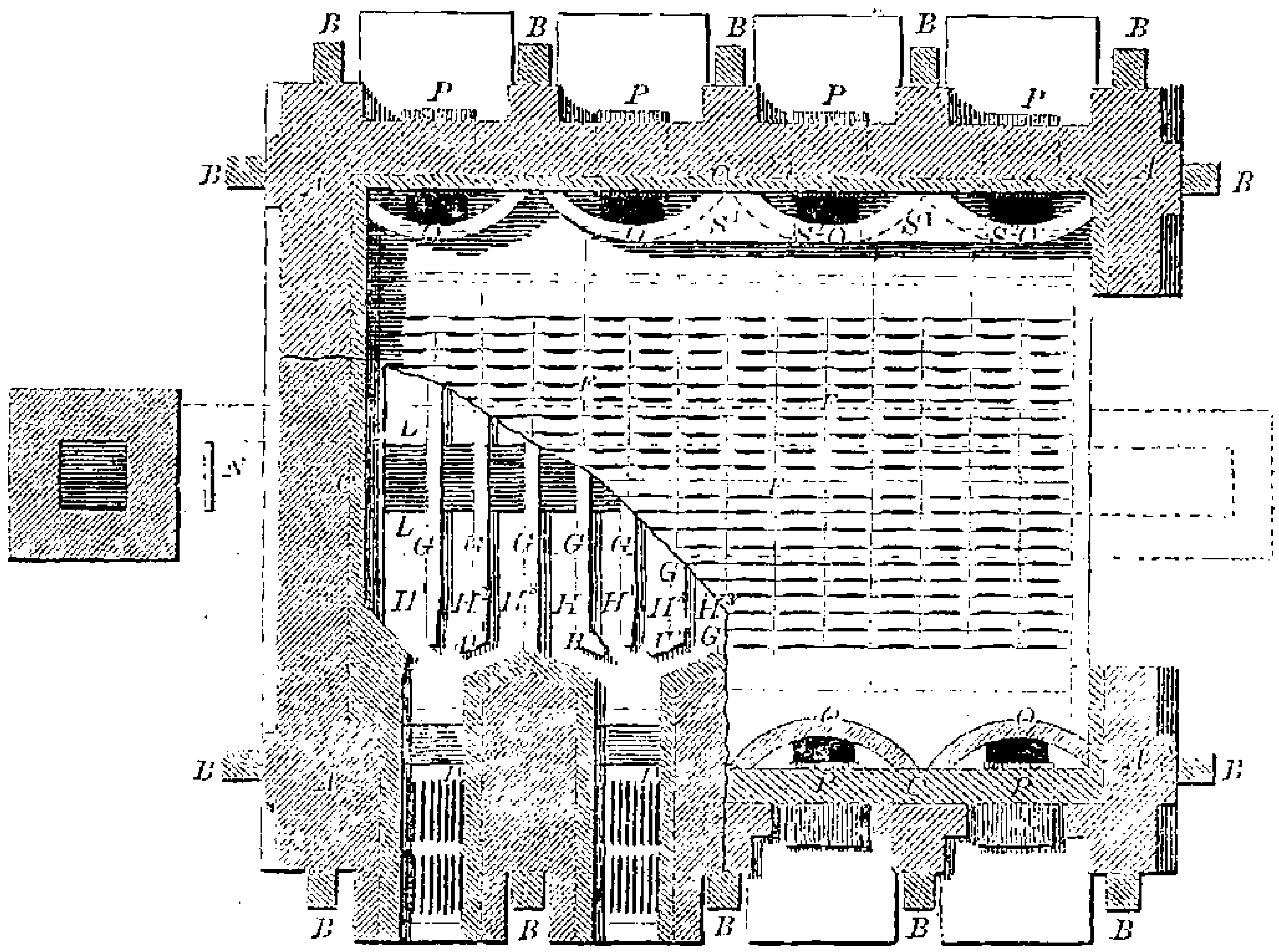
I^1 represents the grate-bars of the fire-chambers and *J* the doors thereto.

K represents the ash-pits.

The flues *H* H^1 H^2 H^3 communicate with a transverse flue *L*, which connects with the chimney or uptake *M*. The communication between the chimney and flue *L* is regulated or entirely closed, as desired, by a damper *N*.

Each fire-chamber is provided with a flue *O*, leading to or near the top of the kiln-chamber. These flues can be closed by dampers *P*.

FIG. 79.



Q are chimneys or outlets on top of the kiln, preferably one for each pair of fire-chambers, where two series are used, and these outlets can be regulated or closed by means of dampers *R*.

The operation of the kiln is as follows: Supposing it is first desired to have the heat and products of combustion pass from the top of the kiln chamber down through the mass of brick, the flues *H* H^1 H^2 H^3 are closed by pieces of brick and refuse matter thrown in through the fire-chambers, the dampers *P* of the flues *O* opened, the dampers *R* of the chimneys *Q* are

closed, and the damper *N* of the chimney *M* is opened. The fires then being started, the heat and products of combustion will pass up through the flues *O*, down through the mass of brick, through the openings *F* into the flues *H* H^1 H^2 H^3, and from thence through the transverse flue *L* to the uptake or chimney *M*, as shown by full arrows, Fig. 78.

When a down draft is used it is important that some means be employed to prevent the heat and products of combustion from taking the shortest course from the tops of the flues *O* to the flues *H* H^1 H^2 H^3, to avoid overburning the brick next to the flues *O*, and to cause an equal burning of the brick throughout the kiln. Furthermore, as the brick are being burned they shrink, forming a flue between them and the sides of the kiln-chamber, down which the heat and products of combustion would be drawn. In order to avoid these difficulties the inventor places tiles, of suitable length, with their lower ends resting upon the upper edge of the outer walls of the flues *O*, and their upper ends resting upon the brick as shown in Fig. 78. Thus the heat and products of combustion are compelled to pass up over the tile before they can descend. As the tile would not rest well if placed directly upon the tops of the semi-circular flues *O*, the inventor first places blocks, S^1, of fire-clay on top of the flues, covering the V-shaped spaces between the flues, as shown in Fig. 79. The inner corners of the blocks are cut off, concave shape, so as not to obstruct the openings of the flues. A common brick S^2 can be placed between the ends of the blocks S^1 to give a uniform height to the tile *S*. One of the blocks S^1 is shown removed in Fig. 79.

T represents peep-holes. (See Fig. 78.)

Then, when an updraft is desired, the flues *H*, H^1, H^2, H^3 are opened by the obstruction being removed, as by means of an instrument introduced through the fire-chambers, the dampers *R* of the chimneys *Q* opened, the dampers *P* of the flues *O* closed, and the damper *N* of the chimney *M* closed. The heat and products of combustion then pass from the fire-chambers to the distributing flues *H*, H^1, H^2, H^3, through the passages or

openings *F*, and up through the mass of brick, escaping through the chimneys *Q*. The draft can thus be changed with very little trouble as many times as desired during the burning of a single kiln of brick. The updraft is shown by dotted arrows, Fig. 78, on one side of the figure, the downdraft being shown on the other side by full arrows, as stated.

The kiln which has just been described can be used to advantage in the burning of fire-clay wares as well as for burning common brick.

CONTINUOUS KILNS.

The principle of the continuous kiln is (1) to use the heat contained in the ready-burnt brick for heating the atmospheric air supporting the combustion, and (2) to use the heat passing away from the fire for heating the green brick yet to be burned.

The first attempt to burn brick continuously was the railway kiln exhibited at the Paris Exposition in 1857. It is not certain who was the inventor of that kiln, whether Collas, Bovie, or who else. The railway kiln, however, did not prove a success, either in Germany, by Mr. Book, or in England, by Mr. Foster. We also know of cases in America where the railway kiln was tried, but likewise without success, the brick coming out of the kiln being "uniformly pale." This was in 1867, at the brickyard of Barnard & Harvey, at Hestonville, on the Pennsylvania Railroad, Philadelphia, where a railway kiln was in use in connection with a Chambers machine. Again, in 1892, at the works of The Anderson Pressed Brick Co., Chicago, Ill.

In the railway kiln a train of platform cars loaded with brick was slowly moved by means of a screw (worm), or hydraulic pump through a long straight tunnel, in the middle of which the fire was burning; from the fire the loaded brick moved toward the end of the tunnel, cooling down while in motion. The draught of air in the tunnel went in the opposite direction, the air entering where the burned brick left the tunnel, passing through the fire and escaping to the chimney at the other end, where the cars loaded with green brick entered the tunnel.

THE HOFFMANN KILN.

In the year 1859 the first Hoffmann kiln was erected in the city of Stettin, Prussia, and in a few years 100 of these kilns were erected in Germany, Austria, England, etc. To-day a very large number of Hoffmann kilns are in operation all over the world, burning brick, including the finest paving-brick, terra-cotta, roofing-tiles, etc. In the United States there are only about a dozen genuine Hoffmann kilns; the first was erected at Carbon Cliff, Rock Island County, Ill., in the year 1866.

In the Hoffmann kiln the brick are not moved during the process of burning, as in the railway kiln; on the contrary, they are set into the burning chamber as in old-fashioned kilns, and the fire is passed through them horizontally, leaving burned brick behind. The burning chamber of the Hoffmann kiln consists of an endless tunnel of an annular shape, either circular, or elliptic, or oblong in plan. This endless tunnel is successively filled with green brick, and after the fire has passed through, leaving the burned brick behind, they are successively taken out when sufficiently cooled down; soon afterward they are replaced by green brick. It takes from ten to sixteen days for the fire to make a round in the Hoffmann kiln; during the same time the whole kiln is once filled with green brick, and once emptied.

It is not possible in the Hoffmann or any other form of continuous kiln to avoid the production of a proportion of soft brick, nor is it possible to obtain satisfactory results in the use of such kilns in burning face and front brick. Continuous kilns are especially adapted for burning common brick with the least possible expenditure for cost of fuel; but it is an open question whether the interest on the large amount of capital necessary to build such kilns, together with the greater wear, tear, and depreciation, and the extra cost for loading the brick upon wheelbarrows, and removing them from the chambers of such kilns, does not more than counterbalance the saving of fuel.

This is especially true in the United States, where fuel is not

so much an item of cost as it is in England and Continental Europe, in which countries the cost of constructing such kilns is also much less, and where the cost of labor for removing the brick on barrows from the kilns is also less than in America. Another drawback in the use of continuous kilns is the fact, although there is certainty of being able to burn the brick in them during all seasons of the year, there is no certainty that the manufacturer can at all times be able to haul brick from his yard, as the weather may not allow it, and the buildings for which he contracts to furnish the brick may not be in condition to require the material only at certain times.

In our own experience we remember that, after having made contracts with the U. S. Government to furnish in one year 17,000,000 brick for the City Hall and other public buildings in Washington City, we seriously contemplated building two Hoffmann kilns on our yard; but were deterred from so doing because of the uncertainty of being able to haul the brick at all times from our works. Some days we could deliver from 100,000 to 125,000 brick per day to the buildings, the large area of dumping ground around the buildings allowing this, and then for three or four days after heavy rains it would be almost impossible to deliver any brick from the yards because of the inclement weather and impassable condition of the roads.

Our conclusion was, if we built the Hoffmann Kilns and went to the expense of wheeling the brick on barrows from the kilns and hacking them in the yard until such times as they could be rapidly hauled to the buildings during favorable weather, or during periods when there would occur delays in setting the stone-work or the iron-beams of each of the stories, that this loss alone would more than neutralize the saving of fuel and labor resulting from the use of such kilns.

In the United States it is not at all a question of being educated up to the use of the Hoffmann or any other form of continuous kiln. The real drawback to their use is that the interest on the large capital required to build such kilns, added to cost of wear, tear, depreciation, and repairs, and the in-

creased cost of setting the brick in them, and the cost of labor for hauling the brick in barrows from the kilns and hacking them in piles and re-delivering them to the carts and wagons, is much greater with us in America than in Europe, where these kilns are in use in large numbers, and where they can be built and operated with profit.

The English as well as the German brick have a volume of about 132 cubic inches (size of English brick 9¾x4¾x2⅝ inches; size of German brick 9¾x4¾x2⅝ inches). For burning 1000 ordinary building brick of this size in old-fashioned kilns, on an average 900 pounds of coal are required, the quantity depending on the nature of the clay as on the quality of the coal. The American brick is of smaller size; the ordinary building brick, in New York, for instance, having a volume of hardly eighty cubic inches. The quantity of coal required for burning these brick is proportionately less, requiring only about one ton of coal to burn about 4000 brick of this size, in old-fashioned kilns. One ton of coal costs in America about $3; the coal for burning 1000 brick in America, therefore, costs about $0.75. According to these figures, the coal for burning 1000 brick in Europe in old-fashioned kilns cost about $1.80 The market price of brick per 1000 is about the same in Europe as in America, common building brick, on an average, selling at $6 per 1000; therefore, in America, the fuel required for burning in old-fashioned kilns only represents about 12½ per cent., while in Europe it represents 30 per cent. of the market price of brick. This difference is caused partly by the difference in the size of the American brick, compared with the European, but is partly offset by the low wages paid in Europe compared with those paid in America.

From the foregoing it is evident that any saving in fuel is of much more importance to the European brickmaker than to the American. It is natural, therefore, that nearly all endeavors to reduce the quantity and cost of fuel required for burning brick have originated in Europe. The Americans, on the other hand, direct their energy and inventive genius chiefly

to lessening the cost of the labor in making and handling the brick, especially through the use of labor-saving machinery.

Mr. Guthrie, a master mechanic of Manchester, England, claims to have invented a modification of the Hoffmann kiln in this respect—that the fuel is generated into gas in furnaces on the outside of the apartment in which the brick are contained; then the brick are burned with the product of combustion, therefore giving a good face brick in all the apartments, wherein the main objection to the Hoffmann kiln is obviated by producing good face brick.

One of these Guthrie kilns is in successful operation at the works of the Columbus Brick and Terra-Cotta Company, of Columbus, Ohio.

There is now no valid patent existing in the United States upon the Hoffmann kiln.

In England and on the Continent of Europe the Hoffmann kilns are commonly built with either twelve or fourteen chambers, twelve chambers answering all purposes where the brick are thoroughly dried before going into the kiln. But when setting direct from the machine, as in the semi-dry process, not less than fourteen chambers, and even sixteen with some clays, are preferable.

As the climate is so much warmer in summer in the United States than in England, these kilns should have not less than fourteen chambers in the one case, and sixteen in the other. The reason is this:

First, in the semi-dry process, in order to be safe from crushing down as a result of too rapid drying, the setting should be at least six chambers ahead of the burning. Between the chambers, in which the setters are at work, and from which the drawers are taken out, there should be three vacant chambers, or it will be too hot for men to work in the summer; and between the chamber from which the brick are being taken out and the chamber just finished firing, there should be not less than three chambers cooling—if four, so much the better every way. By this it will be seen that sixteen chambers are needed;

besides, it is more economical, inasmuch as the air necessary to burn the coal as it is put in through the top has farther to travel through the hot brick, and consequently its heat is intensified in proportion, and so on the other side, in firing, every particle of heat is utilized; so much so that it is possible to stand in the smoke-chamber, at the bottom of the shaft, without inconvenience from either heat or smoke.

Secondly, where brick are dried before setting in the kiln, fourteen chambers will do, still leaving the same vacancies between setters and drawers in summer, but the same advantages accrue on the ground of economy, as in the case of semi-dry process. With these kilns you can use coal that cannot be used in any other, and, if available, gas; or oil is as applicable as to any other kiln. As to the men, a man accustomed to good setting in the ordinary kiln soon becomes proficient with these kilns. The setting must be done well and uniformly, and the man professing to set more than ten thousand per day himself is not the man for the business in these kilns. What is needed is good workmanship, and not bustling; the two qualifications are never found combined.

FIRING THE HOFFMANN KILN.

This department, of course, needs skill, and it is sometimes more easy to train a green hand than an old burner always accustomed to the old-fashioned kilns. The work is much lighter, but requires somewhat closer attention, inasmuch as the firing is done with a small scoop, holding about two pounds of coal, and not a shovel. The coal dust is dropped through apertures in the top of the kiln, and distributed among the brick in its descent to the bottom flues formed in the setting, for the purpose of draft to the cross flue at the end of the chamber (this flue is also formed in the setting) and leading into the main flue connected with the shaft. In the hands of a skillful and careful man, brick can be burnt as uniform and good as in any other kiln in existence, and certainly much cheaper, to say nothing of the advantage accruing therefrom in winter.

With some forms of material it is found impracticable to burn brick with the old-fashioned open kiln. The Fish Pressed Brick Company, of Columbus, Ohio, manufactures a brick made of two-thirds shale and one-third clay, ground in a pan and pressed by the Whittaker Dry-Press Machine. It was found impracticable to burn these brick in the old-fashioned kiln. The company consequently built a continuous kiln having 14 chambers, with a stack over 100 feet in height. The brick are taken directly from the machine and set in the kiln. The chambers are fed with coal-slack or dust; while one kiln is burning, the water-smoke is steaming off three or four chambers. The heat can be controlled so as to burn the best fire-brick or the most tender red brick.

THE DUEBERG KILN.

We may mention two other systems of continuous kilns—the Dueberg kiln and the Mendheim kiln; the former is a modification of the Hoffmann kiln. The green brick are placed on platform cars and those are run into the burning chamber, as in the railway kiln already mentioned. The burning chamber of the Dueberg kiln, however, forms a continuous circuit of rectangular shape, in plan similar to the shape of many Hoffmann kilns. The cars are at rest in the burning chamber during the process of burning, being drawn out of the kiln one by one after the burning is finished and the brick have become sufficiently cool. The fire travels around in the Dueberg kiln exactly in the same manner as in the Hoffmann kiln; coal as well as gas may be used for firing. The principal object in constructing this kiln was to obviate the labor of setting and taking out the brick, to be done inside of the hot arched burning chamber, as in the Hoffmann kiln as well as in other arched kilns, which must be artificially lighted, even in daytime.

THE MENDHEIM KILN.

The Mendheim kiln consists of a combination of a series of arched burning chambers, connected with each other by flues.

so as to form a complete circuit. These kilns are fired by gas and the fire proceeds from one chamber to another, passing through the flues, thus traveling around similarly as in the Hoffmann kiln. The progress of the fire, however, is much slower in the Mendheim kiln, on account of its being compelled to pass through the flues, the area of which is much smaller than that of the burning chambers. For this and other reasons the Mendheim kiln does not afford the same economy in fuel as the Hoffmann kiln.

REGENERATIVE KILNS.

The objects of all late improvements in the regenerative kilns are to thoroughly mix the air and gas burned in such kilns and to effect a better diffusion, regulation, and equalization of the heat obtained from their combustion.

These objects are best effected by constructing in the walls of adjacent kilns duplex hollow spaces or flues, the alternating portions of the opposite sides of which have slits or perforations formed therein, so as to enable the heated products of combustion to be passed or discharged from the lowest part of one kiln into the lowest part of the next kiln—that is to say, the kiln which is being heated preparatory to being fired. These flue-spaces are provided with vertical or horizontal dampers, so as to shut off the communication between the kilns, the slits or perforations in the flue-spaces effecting the improved diffusion. In place of forming such flues in the walls of the adjacent kilns, flues may be formed in the brick-work outside the wall, in which case the air descends some distance below the floor of the kiln, where it passes through ports, regulated by dampers, into a still lower flue, from which it escapes through slits or perforations formed in the lower part of the walls into the burner or chamber, or opening, wherein it mixes with the gas. For the purpose of admitting either hot air into the upper part of the kilns from an adjacent kiln, or for the purpose of admitting cold air to the upper part of a kiln being fired, a similar flue—that is to say, either duplex or

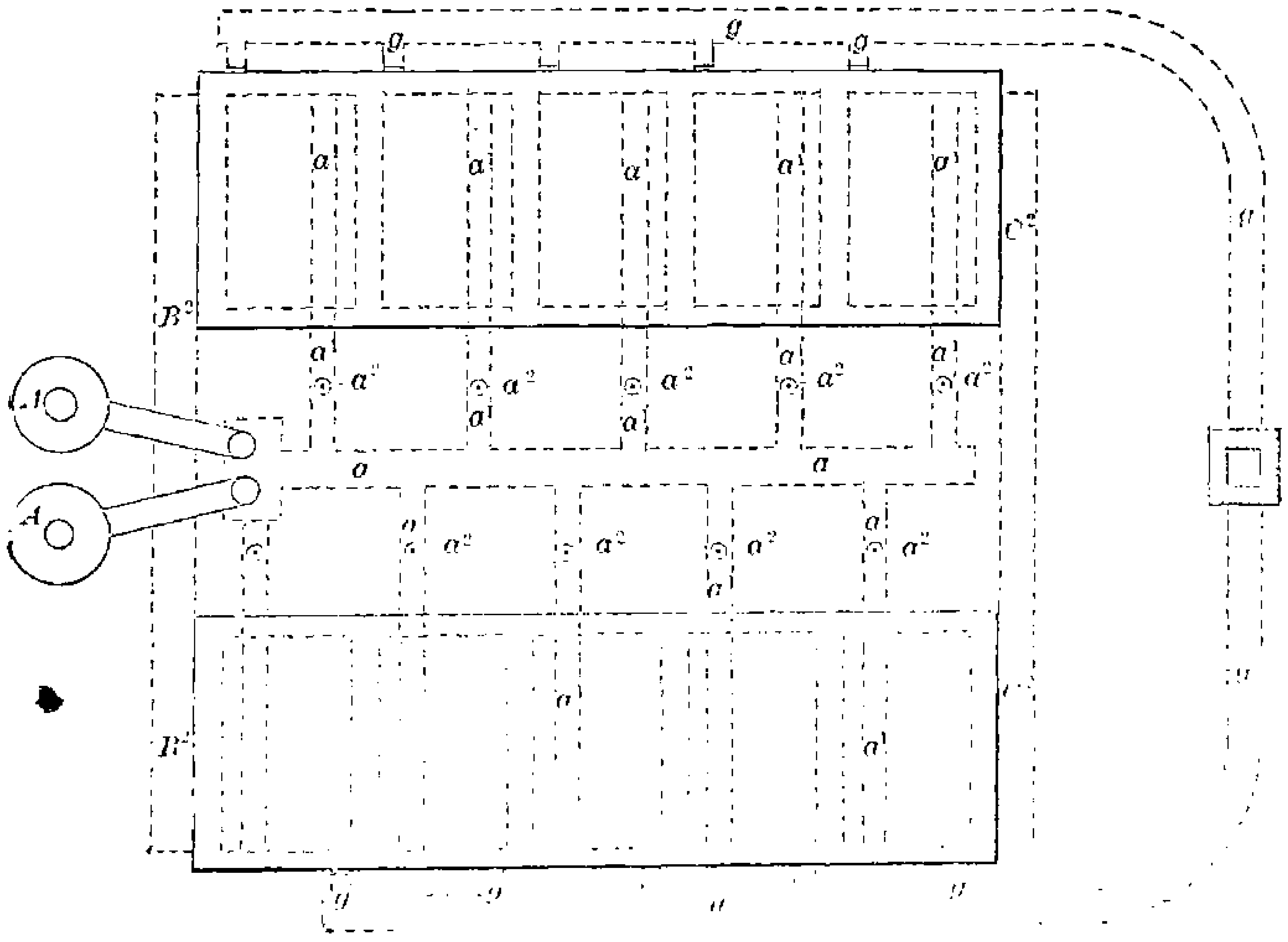
single—is provided with dampers and with slits or perforations in its opposite sides in the walls at or near to the upper part of the kilns. Either hot or cold air is admitted through these upper flues and slits or perforations, when the air admitted at the lower part of the kilns with the gas may be either deficient in quantity to produce complete combustion, or when the temperature of a kiln at its upper part may be either too high or too low. In place of making the flues duplex, with slits or perforations, as before described, they may be made single, with one side—namely, that through which the discharge takes place—constructed with one, two, or more larger openings in lieu of slits or perforations above or at a level with the bottom of the kiln, and with slits or perforations at the opposite side.

The regenerative principle just described may also be applied to calcining-kilns and other analogous apparatus.

THE DUNNACHIE KILN.

Mr. James Dunnachie, of the Glenboig Union Fire-clay Works, Glasgow, Scotland, has recently perfected an improved

FIG. 80.



regenerative kiln for burning fire-brick, which is constructed upon the principles just described, and for which Charles T. Davis, of Washington, D. C., is the agent in the United States.

Figs. 80 to 88 represent the Dunnachie kilns arranged in two opposite rows or series of five each, the end kiln of each

FIG. 81.

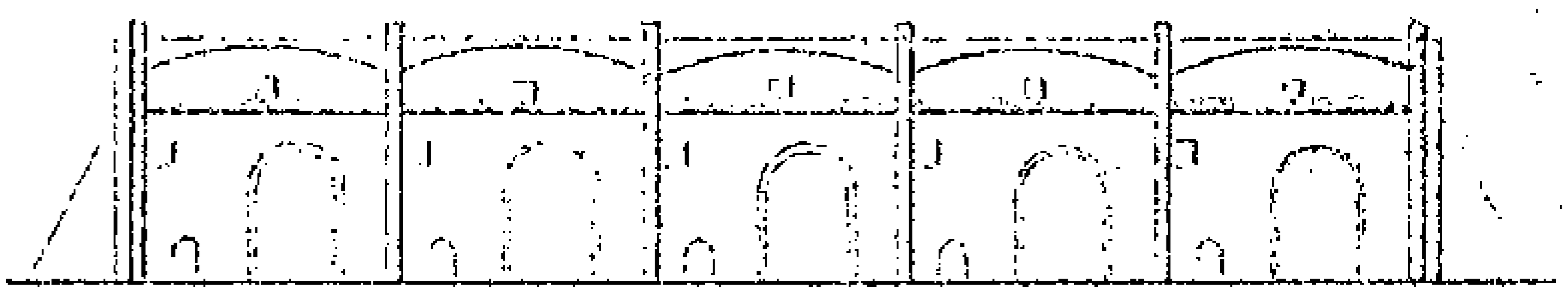


FIG. 82.

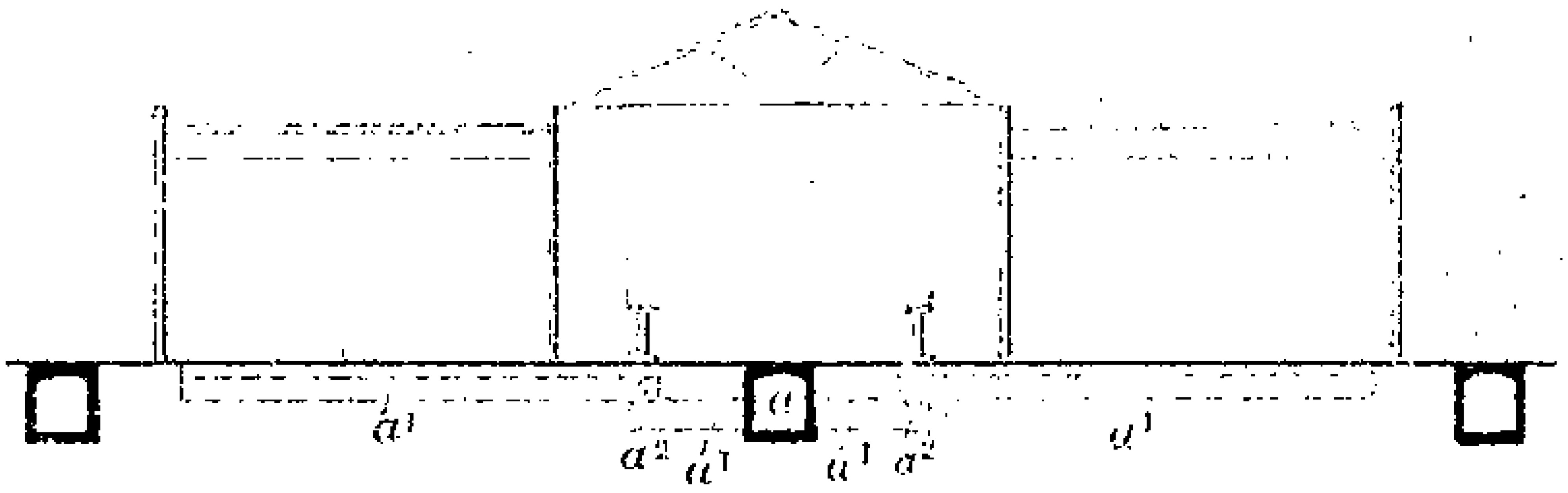
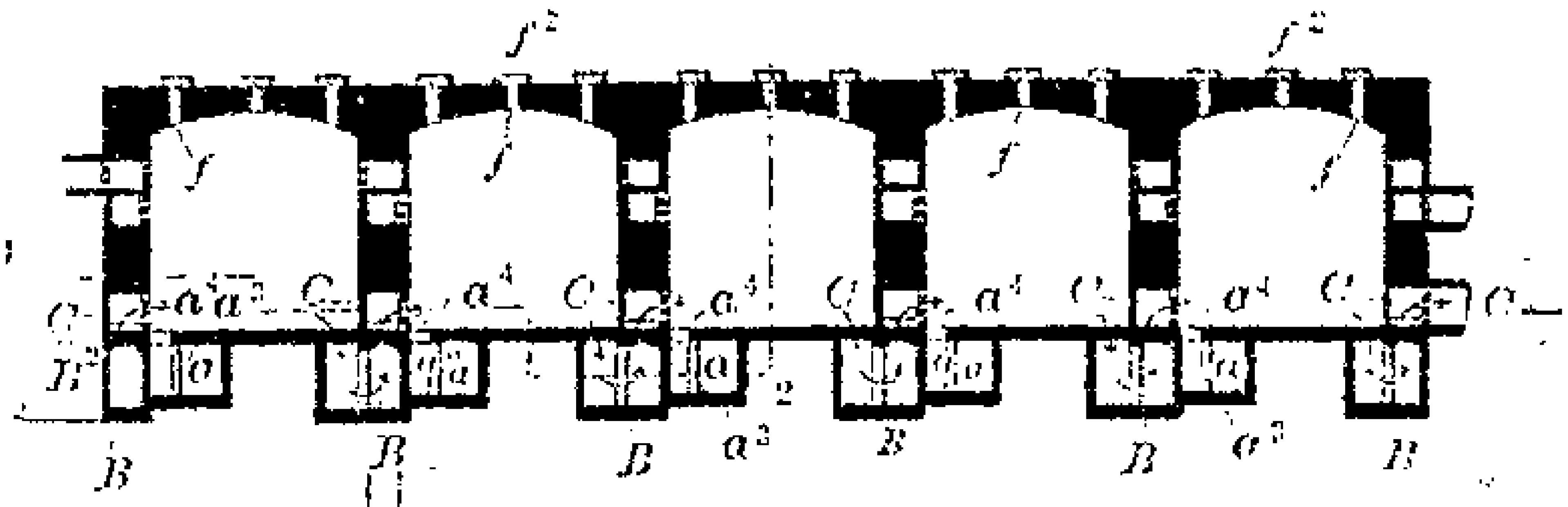


FIG. 83.



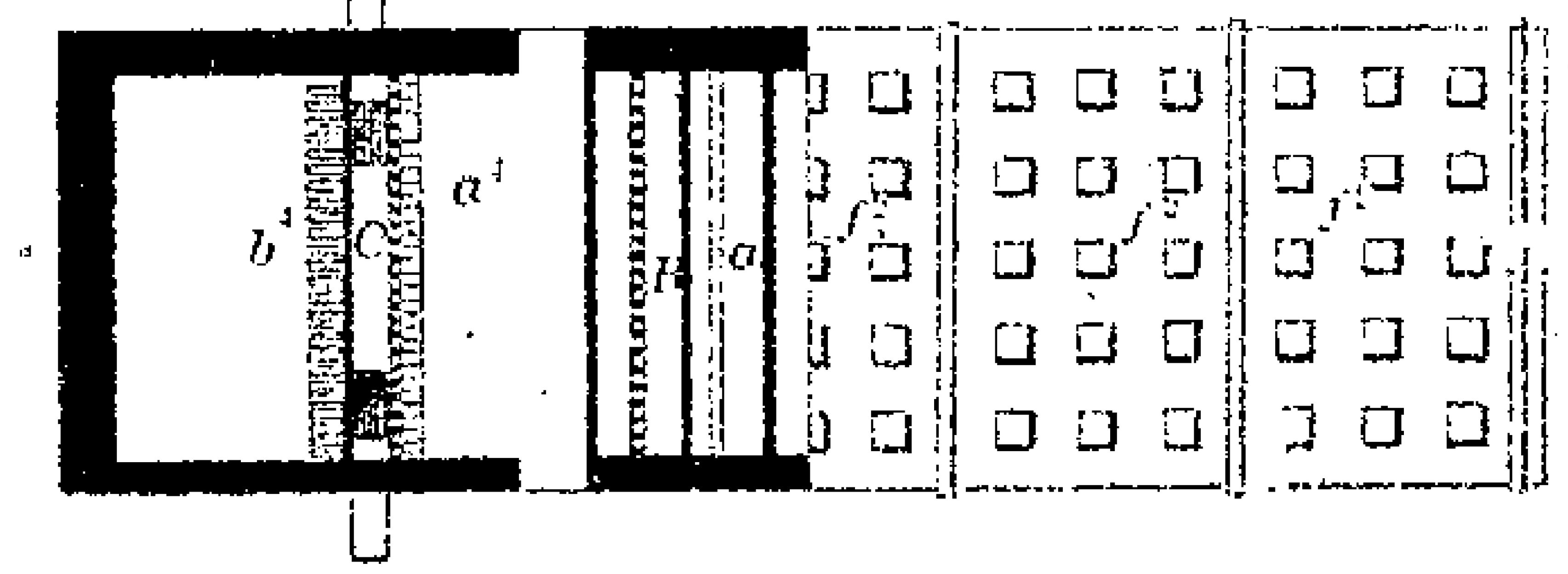


FIG. 84.

series being connected to the corresponding end kilns of the other series by means of flues.

Fig. 80 is a general plan of the series of kilns. Fig. 81 is an end elevation of the same. Fig. 82 is a front elevation of one of the series or rows. Fig. 83 is a longitudinal vertical section of the same. Fig. 84 is a plan of the same, partly in section, on the line 1 2, Fig. 83.

The following figures are drawn to a larger scale, the beter to exhibit the flues and passages: Fig. 85 is a longitudinal vertical section of a kiln of the series, with portions of the adjacent kilns on either side. Fig. 86 shows one-half of a horizontal section of the same, taken on the lines 3 4, Fig. 85. Fig. 87 is a vertical transverse section on the line 5 6, Fig. 85, showing the side wall of the kiln, indicated by the arrow 7. Fig. 88 is a section on the line 5 8, Fig. 85, but showing the other side wall of the kiln, as indicated by the arrow 9.

Fig. 85.

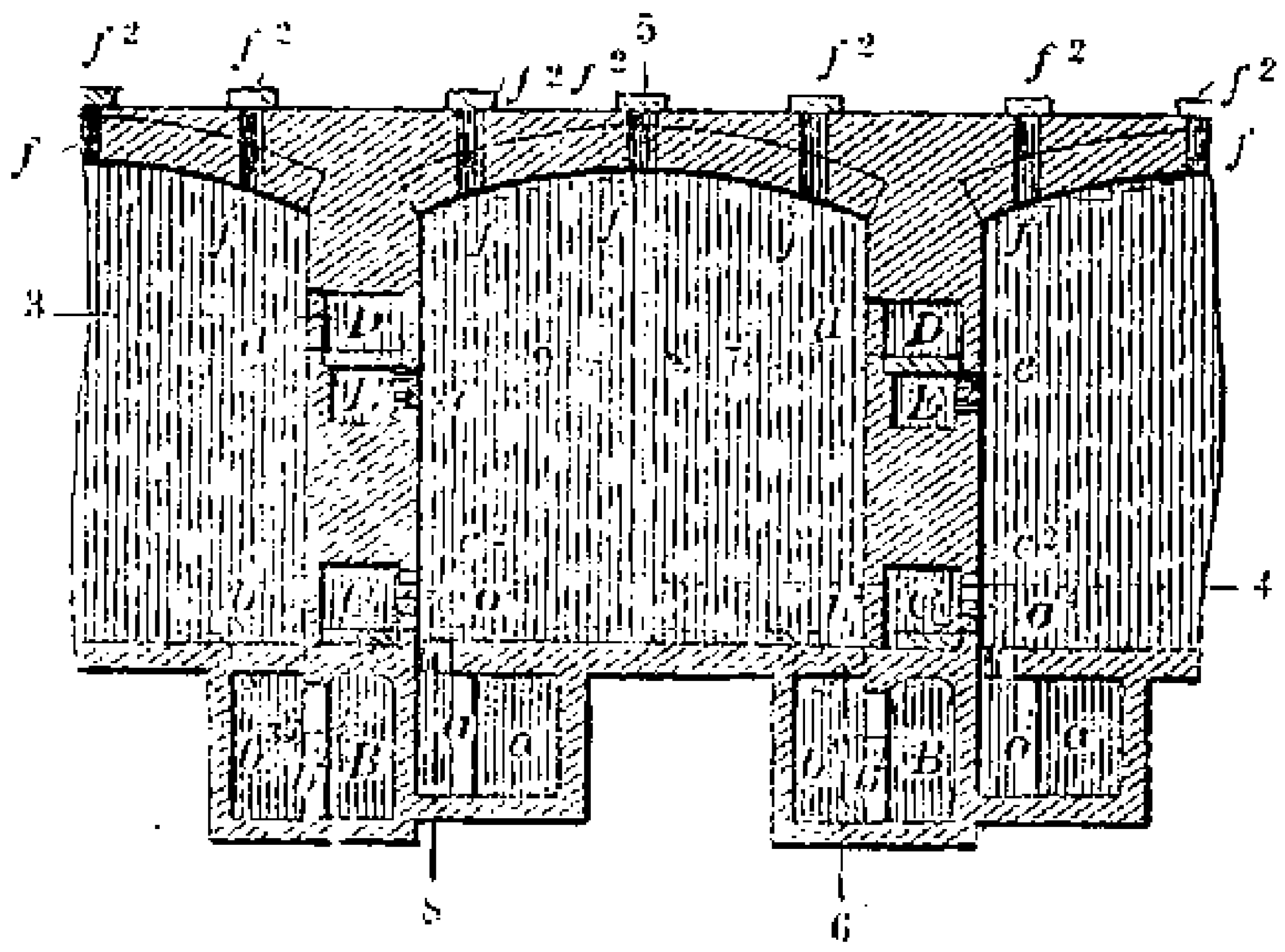
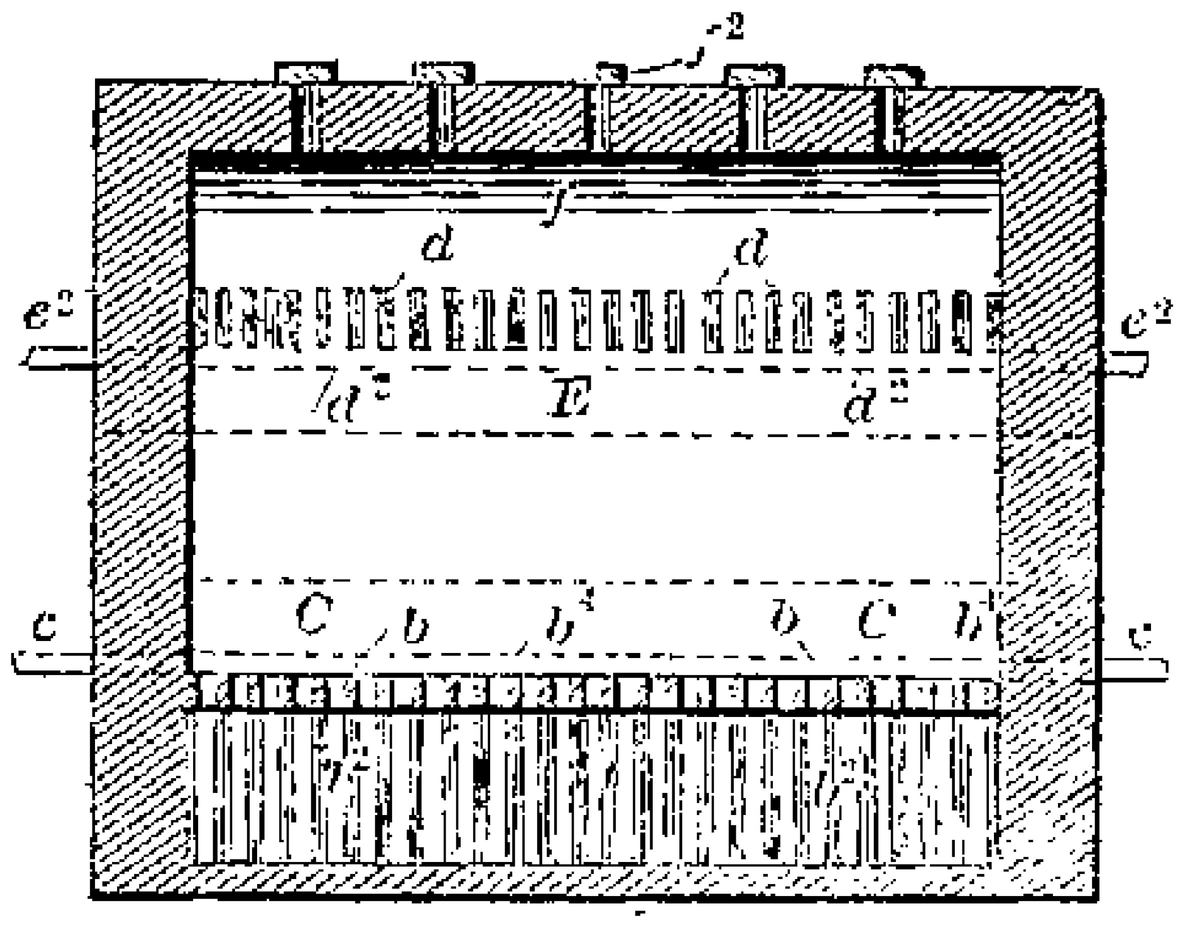


Fig. 87.



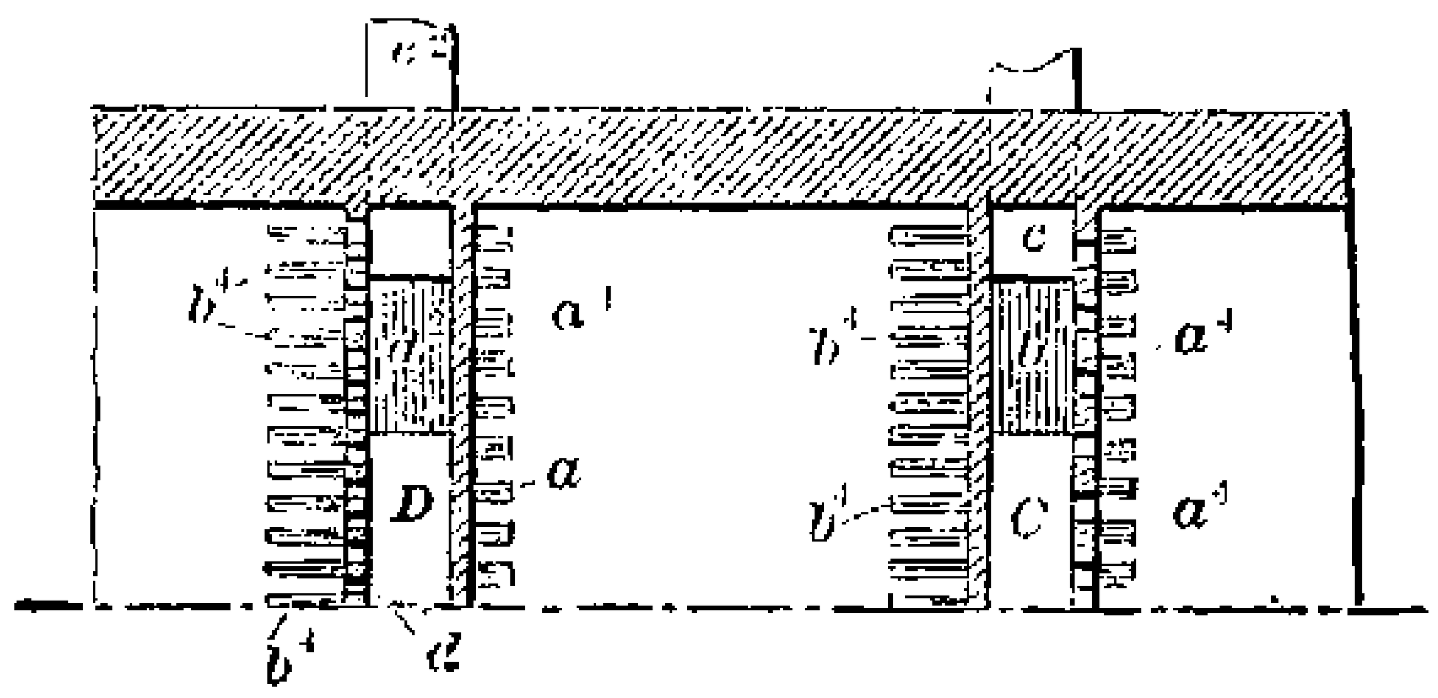


Fig. 86.

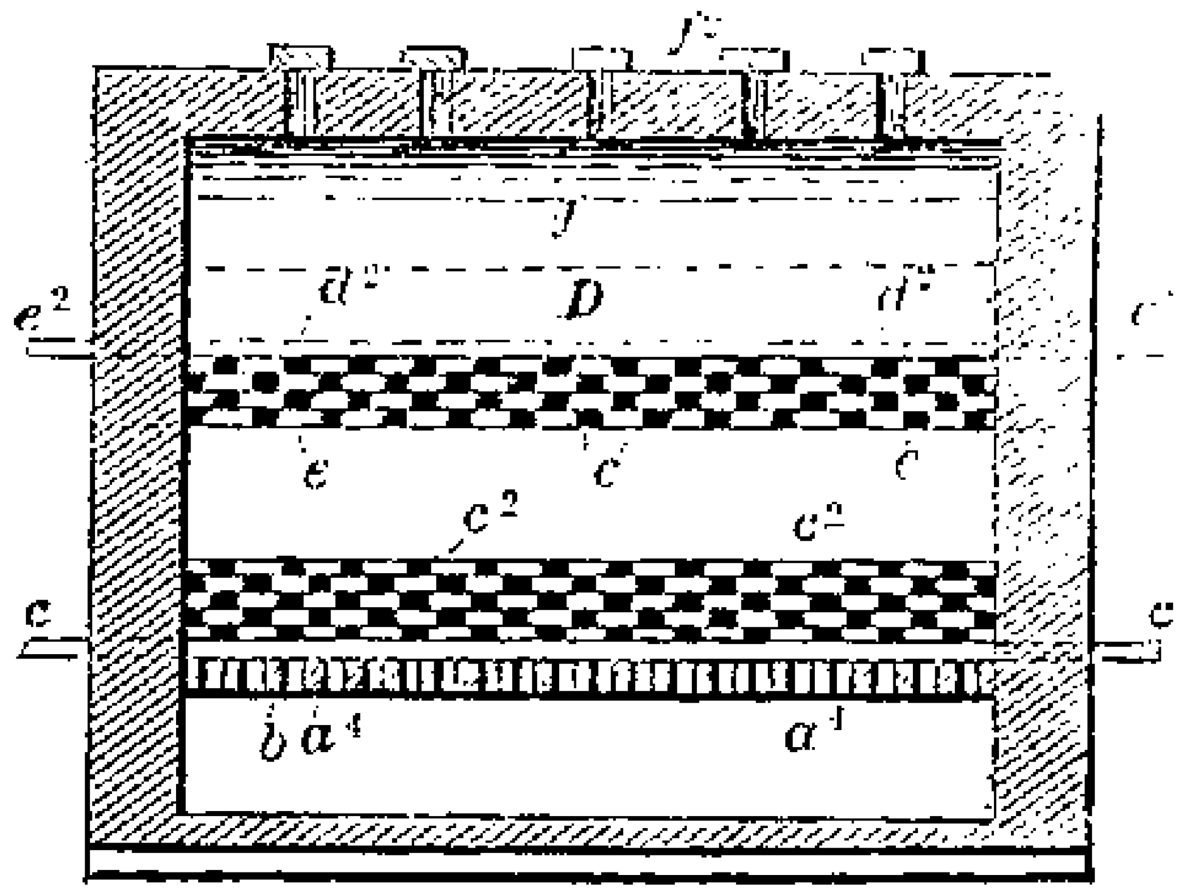


Fig. 88.

The gas to be employed for the burning process is obtained from any convenient source. For example, it is produced in gas-producers, indicated at *A*, Fig. 80, and is led threfrom by the main passage *a*, wherefrom lead branch passages a^1 for the gas to each kiln, a valve a^2 being upon each such passage to regulate the supply of gas to each kiln. The gas passes into the kilns by openings a^3 and a^4. In the division walls which separate the kilns are duplex hollow spaces or flues (marked respectively *B* and *C*), communicating the one with the other by

openings *b*, which openings are regulated or closed by dampers *c*. In the side of the flue *C* are passages c^2, opening from the flue just above the outlets for gas a^1 in the one kiln, the flue *B* being in communication by the slots b^2, passage or flue b^3, and slots b^1 with the lower part of the adjacent flue. A duplex passage consisting of flues *D* and *E* is also formed in the upper part of the walls of the kilns, the one passage *D* communicating by means of the openings *d* with the one kiln, and the other passage *E* communicating by means of the openings *e* with the adjacent kiln. The flues *D* and *E* communicate with each other by openings d^2, which can be regulated by dampers e^2. Openings *f* are made in the roofs of the kilns, which openings are covered by slabs or dampers f^2.

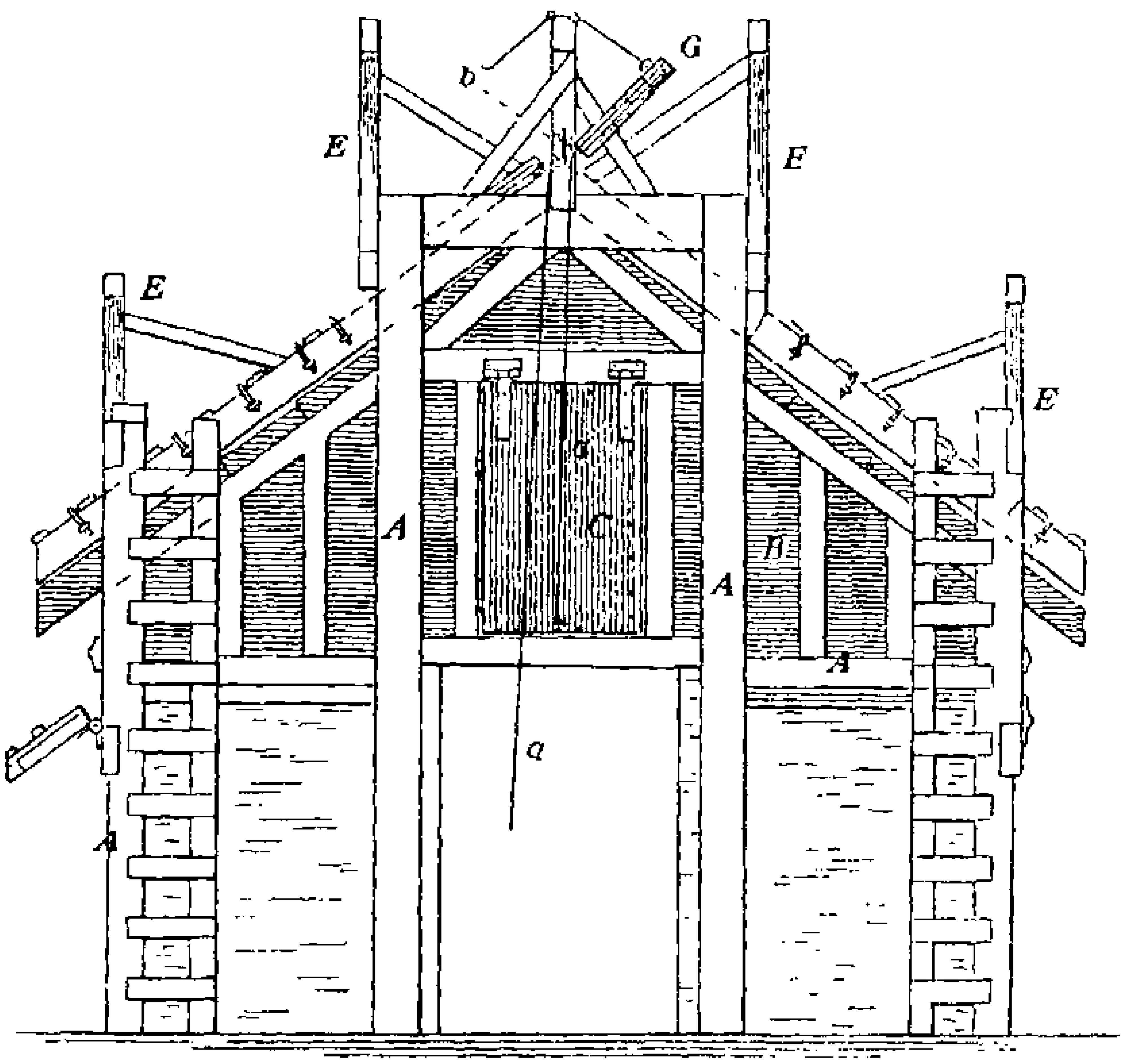
In operation, when one kiln is in fire the effluent gases produced therein are passed into the adjacent kilns through the openings b^1, passage b^3, openings b^2, passage *B*, openings *b*, and passage *C* into the adjacent kiln next in the series through the openings c^2, and will heat the contents of the kiln. When the first kiln has been fired off the air passes through that kiln into the adjacent one through the passages *B* and *C*, as before described, issuing thereinto by the openings c^2. Gas is then turned on to this kiln, and, meeting with hot air, burns and bakes the brick. The quantity of air passing through the one kiln to be heated on its passage to the adjacent one is regulated by the dampers *c*, and the quantity of gas admitted to this kiln is regulated by the valve *a*. When this last-mentioned kiln is burned off, the supply of gas is turned off therefrom, and this one becomes in its turn the regenerator or heater of air for the next kiln, and so on through the series, the passages marked B^2 and C^2 in Fig. 80 giving free communication between the respective end kilns of each row of kilns. If it is desired to admit hot air to the upper part of any kilns, this may be done by opening the dampers f^2 at the top of a fired-off kiln, and air heated by the kiln thus being caused to pass from the kiln through the openings *d*, passage *D*, openings d^2, and passage *E*, and into the adjacent kilns through the openings *e* to raise

the temperature of the upper part of the kiln, or to assist in the combustion of the gas, Where cold air is to be admitted, air passes through the flue *E*, which is open to the atmosphere at both ends. The outlet-passages from each kiln, and the main flues to the chimney into which these passages open, are indicated in Fig. 80, and are there marked *g*.

PERMANENT KILN ROOFS.

By having the roof permanent, a great saving of labor in taking off and putting on an ordinary wooden roof is effected, and the waste incident to the repeated handling of the boards is obviated. It renders the brickmaker independent of the

FIG. 89.



weather, as his kiln is covered at all times, and the doors can be shut down more or less during a storm. It saves fuel, as the heat cannot escape so rapidly, and the proportion of hard-burned brick is largely increased, and a much greater uniformity of color throughout is secured.

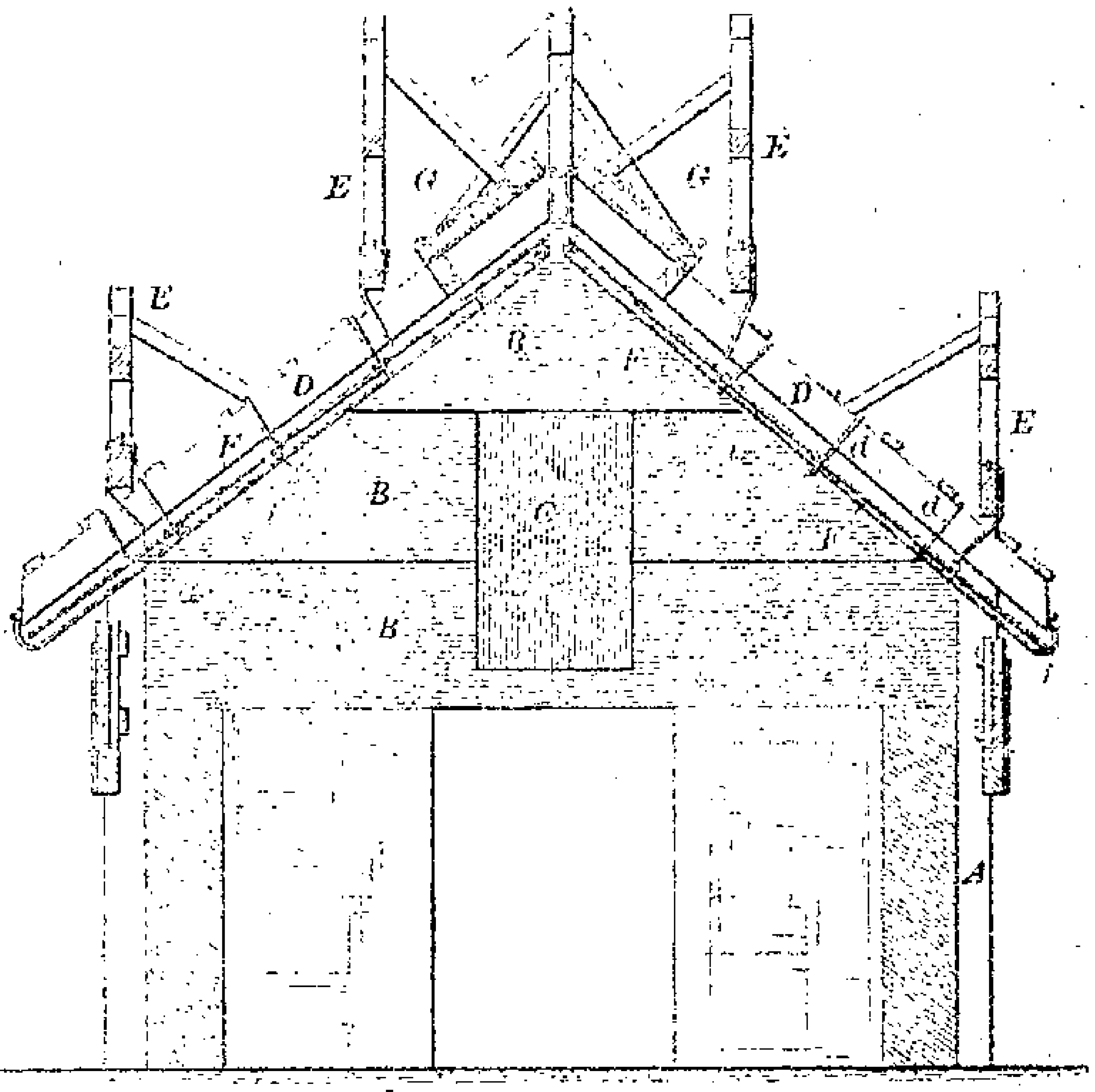
The kiln roof shown in Figs. 89, 90, and 91 is the invention

of Mr. Thos. F. Adams, of Philadelphia, Pa., and it is in use at the works of the Peerless Brick Company in that city, which company controls the patent right.

The roof is permanent on the kiln, and enables the burner to manage the direction of the heat, and by closing and opening the doors he can create a draft at any part of the kiln he may desire.

Fig. 89 is an end elevation of a brick-kiln embodying this invention. Fig. 90 is the transverse vertical section of the same. Fig. 91 is a detail view of a part thereof.

FIG. 90.



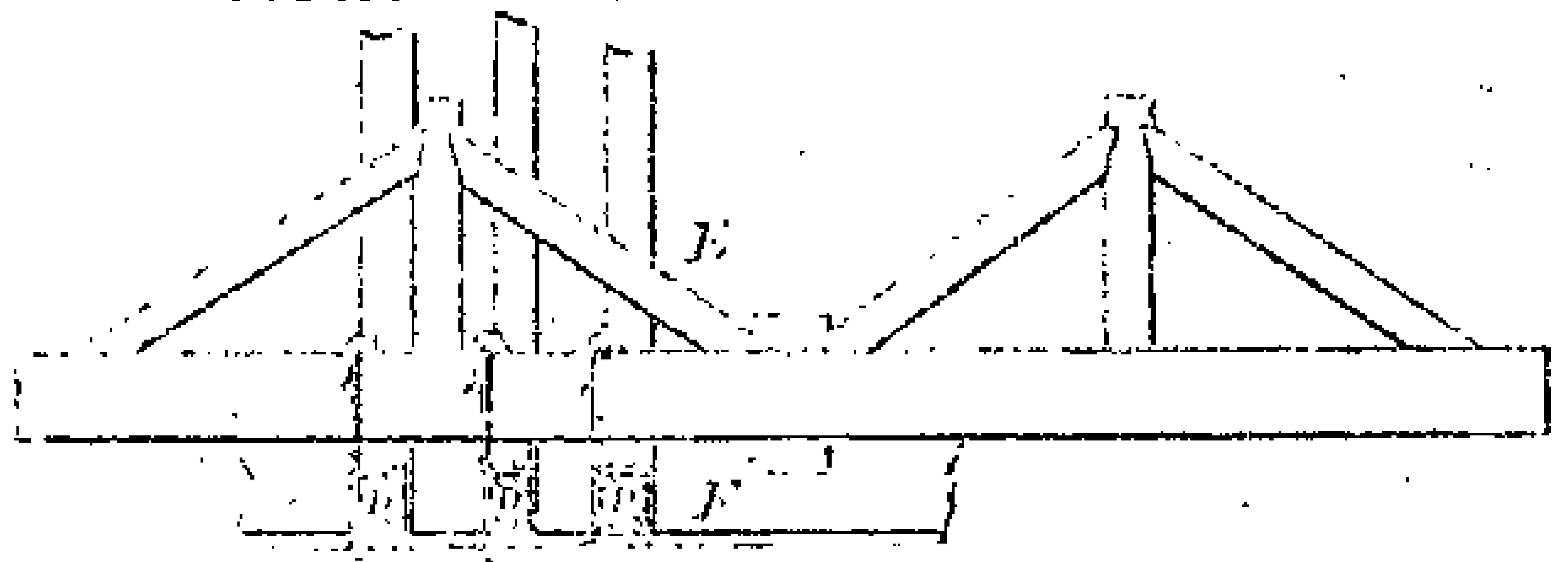


FIG. 91.

A represents the ordinary frame-work of a brick-kiln, which is boarded up to a certain height. At each end are then applied sheets *B B*, of iron, to complete the gable, and in the

same is made a door *C*, which is hinged at its upper end, and provided with a chain *a*, passing over pulley *b*, at the top of the frame, so that the door can be opened more or less from the ground, as may be desired.

To the frame-work *A* are connected suitable upright truss-frames *E E*, standing above the kiln on each side, and to these are secured rafters *D D* on each side, the rafters meeting at the top in the centre, and sloping downward on each side below the truss-frames.

The roof of the kiln is composed of iron sheets *F F*, which are suspended from the rafters by hooks or stirrups *d d*, passing through the sheets and fastening in rods *i*, running from the top to the lower edge of the roof on each side.

At the top in the roof thus formed, are made hinged doors *G G*, to be opened more or less, as occasion may require.

The iron roof *F* is suspended about an inch below the rafters, so as to prevent any liability of the wood catching fire.

CHAPTER X.

THE MANUFACTURE OF FIRE-BRICK; SILICA FIRE-BRICK; CARBON FIRE-BRICK FOR FURNACES; GLASS POTS AND GAS RETORTS.

THE essential qualities of a good fire-brick may be stated as follows: First, infusibility; second, regularity of shape and the power to retain it under all circumstances, which involves perfect uniformity of composition; third, strength to resist the different pressures required under different circumstances; and fourth, its cheap price. No material yet manufactured fulfills all these conditions; but there seems to be no reason why, with the proper investigation, a material should not be made which will fulfill most of the requirements above stated. No brick can come up to the modern standard of infusibility which contains 5 per cent. of iron, or 3 per cent. of combined alkalies or alkaline earths; and yet the most infusible brick that is known, which in the roof of a Siemens-Martin furnace will resist 250 charges, and then wear out by abrasion, when required to come in contact with metals, oxides and alkalies in a spiegel cupola, will hardly stand 25 heats, although an iron-pipe coil, which is easily destroyed by heat, will last almost indefinitely in the same cupola, provided only a sufficient stream of water is run through it. Different furnaces, and different parts of the same furnace, should, therefore, be treated differently, instead of being treated by the same procrustean methods, as is frequently the case. If silica makes the best roof, it makes the worst hearth. Alumina, when present in very large quantities, even in the presence of a small amount of silica, makes compounds which are almost infusible, so that it should be used for the fire-bridges and hearths, and not be

put into the roof, where its tendency to contract would endanger the structure of the furnace.

Far too little attention has been given to the abrasive and corrosive power of coal-dust and ashes carried by the draft in gradually cutting and fluxing away the parts of the furnace exposed to its action, and many qualities of brick which are infusible in the assay, owe their small power of resistance to its effect. A brick to be used where it is to be exposed to such action should always be tested by placing it for a considerable time on the bridge of the furnace where it is to be used, for the destructive effects of this almost unobserved agency seem to be greater than those of long-continued heat.

A good brick should not only resist high temperatures, but sudden changes of temperature, without alteration of any kind; such as crushing, splitting, etc., and at a high temperature, should undergo the least possible change of form. In general, it may be said that brick which have undergone a very high temperature in the manufacture are less liable to contract afterward. Shrinkage is generally due to insufficient burning, or to a small proportion of old material in the mixture, and generally occurs in aluminous brick. Its chief evil is in allowing the flame to penetrate the open joints and give the dust an opportunity to cut between the brick, for any cause which produces eddies in the flames, such as hollows or projecting surfaces, is certain to effect the destruction of that part of the furnace.

Refractory materials may be classified as fire-stones and fire-clays. The former are usually silicious rocks, but sometimes talcose slates or soapstones are used, which stand heat well in the presence of basic slags. All fire-stones are used in the native state, with no other preparation than the necessary shaping. Fire-clay is the main refractory material, and is used only in the manufactured state.

Many managers of rolling-mills have condemned a first-class fire-brick because the crown, or roof, of the puddling furnace had worn in an irregular manner, holes or eddies being worn through the whole depth of the brick, while the brick in the

same roof and immediately around are nearly of original length. The fire-brick manufacturer receives the complaint and is sorry to lose his customer without any personal investigation, or probably he may run over and see for himself. He sees an irregular roof with holes fused through, or nearly so, and the bulk in good condition, and is at a loss to explain the reason. He may be satisfied in his own mind that the brick he sent were all of the same quality, and so tell the manager. This failure may, perhaps, have been caused by some No. 2 quality having become mixed with the others in loading, or very probably, as I have found myself under such circumstances, that the bricklayers wanted some keys or wedges to get the proper radius, and have been obliged to take a make of brick of another manufacture and of inferior quality from the stock-house. These have fused more readily, as they have worn past the other brick, forming holes or eddies in which the flames and dust have played, thus destroying the inferior brick much more rapidly than if the whole roof had been built with them.

A practical manufacturer or salesman, who understands his business, would in such case, go over and investigate; he would take pieces of the longest brick least damaged, and pieces of the small ends where most worn, and examine the fracture of same; he might then come to the same conclusion as we have done under such circumstances. He would say to the manager, "Look at these two fractures; they are not the same brick or the same material; the inferior brick is some other manufacture." Then take the pieces into the stockhouse and compare. Thus, in place of losing a customer, you increase the popularity of your own brick. This irregular wearing in furnace roofs is very important to the mill men, as it is necessary that the roof be perfectly even that the flame may have a clear flow, as in case of its obstruction by uneven tops or eddies, it is not only destroying the fire-brick, but retarding the manufacture of the iron.

Silicious brick have a tendency to expand under the influence of intense heat. This is true to such an extent that in the steel

furnaces where they are used, provision must be made for slackening the tie-rods when the fire is being raised, and tightening them when it is being cooled.

The crushing weight of an ordinary fire-brick is from 600 to 1000 pounds, but some of the best have been known to resist as high as 3000 pounds to the square inch. To insure the safety of the structure, and the success of the process, it should not only retain its power of resistance, but should not undergo any change of form nor soften materially under long-continued heat, and at the highest possible temperature should support more than double the strain required without alteration. In the walls of the fire-place those brick will be best which are dense, and contain an excess of silica. In the hearth they should contain an excess of alumina. In the arch they should be nearly pure silica, alumina or magnesia. Brick in a roof give out from shrinkage, cracking or splintering. Splintering may take place when silicate brick are made of impure mixture, but it is usually caused from too much fine material and from imperfect burning. Brick which are liable to splinter are generally cross-grained and dense, with a smooth conchoidal fracture, when made from improper mixtures, and when badly burned they generally sound like a cracked vessel when they are struck together. All good brick wear off evenly.

No matter how good a material may be, if its price is so high as to prevent healthful competition, it might as well not be produced. Hence any effort to furnish a good material should have for its aim to make it at the least possible cost.

In discussing the manufacture of a refractory material which is to be used in a given locality, there is to be taken into account, first, the clay and other materials to be had; second, the ore or metal to be treated; third, the fuel to be used; and fourth, the foreign substances in the gangue of the ore or metal. Whether to use a given clay, or a mixture of calcined or raw clay, must be determined by direct experiment, and then the size of the grains of the mixture for the special use must be determined, for each substance is more or less refrac-

tory according as it is coarse or fine. Thus, in Belgium a porous material with a large grain is used for blast-furnace brick, but a fine material with a close grain for coke-furnaces, the chemical composition being the same in both cases. It must then be ascertained whether the mixture contracts or expands, for there are clays that contract and expand between one-thirty-second and one-eighth of their bulk. The way in which material tempers must then be carefully studied. It is not sufficient to have a good material, for almost as much depends on its manipulation as on the material itself. To temper properly, the clay and the manufactured article should both be dried gradually and uniformly. It must be fired evenly, and the temperature slowly raised to the proper point. If it is to be used in the raw state as ganister, it must be equally moist throughout, so as to dry uniformly, and not so wet as to cause it to crack in drying, or so dry as to prevent its binding. The brick, or other materials, once made, should be kept from dampness; as they are porous, and likely to absorb moisture; they should be heated before being used in the furnace, and put in as hot as it is possible to handle them. If the furnace is in blast, this requires a special furnace and a high heat. If it is to be put in blast at once, especially with silica brick, the temperature should be as high as the hand can bear. If the surface is to be a long time standing, this precaution is not necessary, but in the last two cases the furnace must be dried very carefully and slowly. No brick which has been dressed should ever have the dressed face exposed to the flame. Without the observation of these precautions a really good brick may give a very bad result. It is too much the habit of this age to be in a hurry to get results, and this has led some blast-furnace managers to boast that steam was issuing from the top of their furnace while cast-iron was being tapped from the bottom; but under such management we never hear of long campaigns, but very frequently hear of disasters.

It is thus seen that a brick which is good for the cupola would be worthless for the reverberatory furnace; that which

answers well for iron would generally be worthless for zinc, and a crucible which is excellent for steel cannot be used for brass. It is not the way to realize progress to keep analyzing natural substances until we find the right one, or make repeated trials and depend upon them alone. All investigations go to show that we should look for artificial, and not for natural compounds; and that when we have made a mixture which has stood well, we are then to analyze and examine it in order to reproduce it. Failure in this, as in many other cases, is very often owing to wrong application of good materials, rather than fault in the materials themselves.

When broken, fire-brick of good quality should show a compact and uniformly grained structure, free from cracks, stones, etc. When struck, they should emit a clear and ringing sound. The expansion of ordinary fire-brick by heat in rising from 32° F. to 212° F. is .00005, according to Rankine. All fire-brick forming the lining of chimney-shafts should be set in ground fire-clay mixed with water to the consistency of mortar. The brick are sometimes, before being laid, dipped into a liquid or creamy fire-clay, and when laid in place hammered together so as to be, when finished, brick and brick. This method is now largely adopted, and answers admirably where the temperature is high.

A properly burned brick, uniform throughout its mass, can be obtained only by very slow progressive firing; a broken brick which has been too quickly burned, though pale on the surface, presents a darker central patch and concentric rings of various shades of color, due principally to the different states of oxidation of the iron, and partly to the presence of unconsumed carbonaceous matter.

A well-manufactured fire-brick should be of a pale cream or clear buff color, uniform throughout its mass, and burned to the full extent of its contractibility.

The chemical changes which take place in the burning consist, first, of the destruction of the disseminated carbonaceous matter, the dehydration of the silicates of alumina, destroying

their plastic character, and the decomposition of the disseminated carbonate or protoxide of iron, converting it into anhydrous sesquioxide to which the yellow of the burned brick is due.

Should the burning be carried to a very high state of vitrification the yellow tint is replaced by a dull gray, due to the partial reduction of the sesquioxide of iron, and its conversion into silicate of protoxide or minutely disseminated particles of metallic iron. Any alkalies also present form vitreous combinations with the silica during the latter stages of the burning.

But the paleness of color of a fire-brick is not at all times a safe indication of the absence of iron, as the presence of a large proportion of carbonaceous matter in the clay tends to bleaching by the reduction of the coloring sesquioxide to lower oxide preserved as a silicate in a comparatively colorless condition. Then, again, the presence of lime and the other alkaline earths, which are disadvantageous fluxing elements, will check the coloring power of a large percentage of oxide of iron by the formation of a pale double silicate of lime and iron. This is largely taken advantage of in the manufacture of buff-colored building brick, and, we are also very sorry to add, in the production of buff-colored terra cotta, by mixing ground chalk with ferruginous clays which would otherwise burn a dark red color.

If the practical manufacturer wants a brick to yield slowly to corrosive influence, a simple test to apply is, to ascertain the number of times which the brick can be melted with oxide of lead and not be eaten through. In fire-brick constructions the use of joints of clay containing free silicic acid (quartz) should be avoided, which can be done by previously saturating the material with a basic burnt clay.

When good fire-brick are used, it is important that clay equally as good as that from which the brick are made should be employed in which to lay them. When ordering, brick consumers should also send their order to the same fire-brick manufacturer from whom they purchase brick, for clay of the same quality. These clays are usually kept in stock, and fire-

brick manufacturers can furnish them ground, either raw or calcined, in bags of 100 pounds each, or in barrels or in bulk, as may be desired. From 600 to 800 pounds, according to the way the clay is used, is sufficient to lay one thousand nine-inch brick.

It is recommended that No. 1 clay be used with No. 1 brick. The brick should be "dipped" in a thick "soup" of ground clay, similar in character to that from which the brick used are made. There are few points which will so well repay consumers of fire-brick as this "dipping" will do, as the comparative first cost of the fire-clay is only trifling.

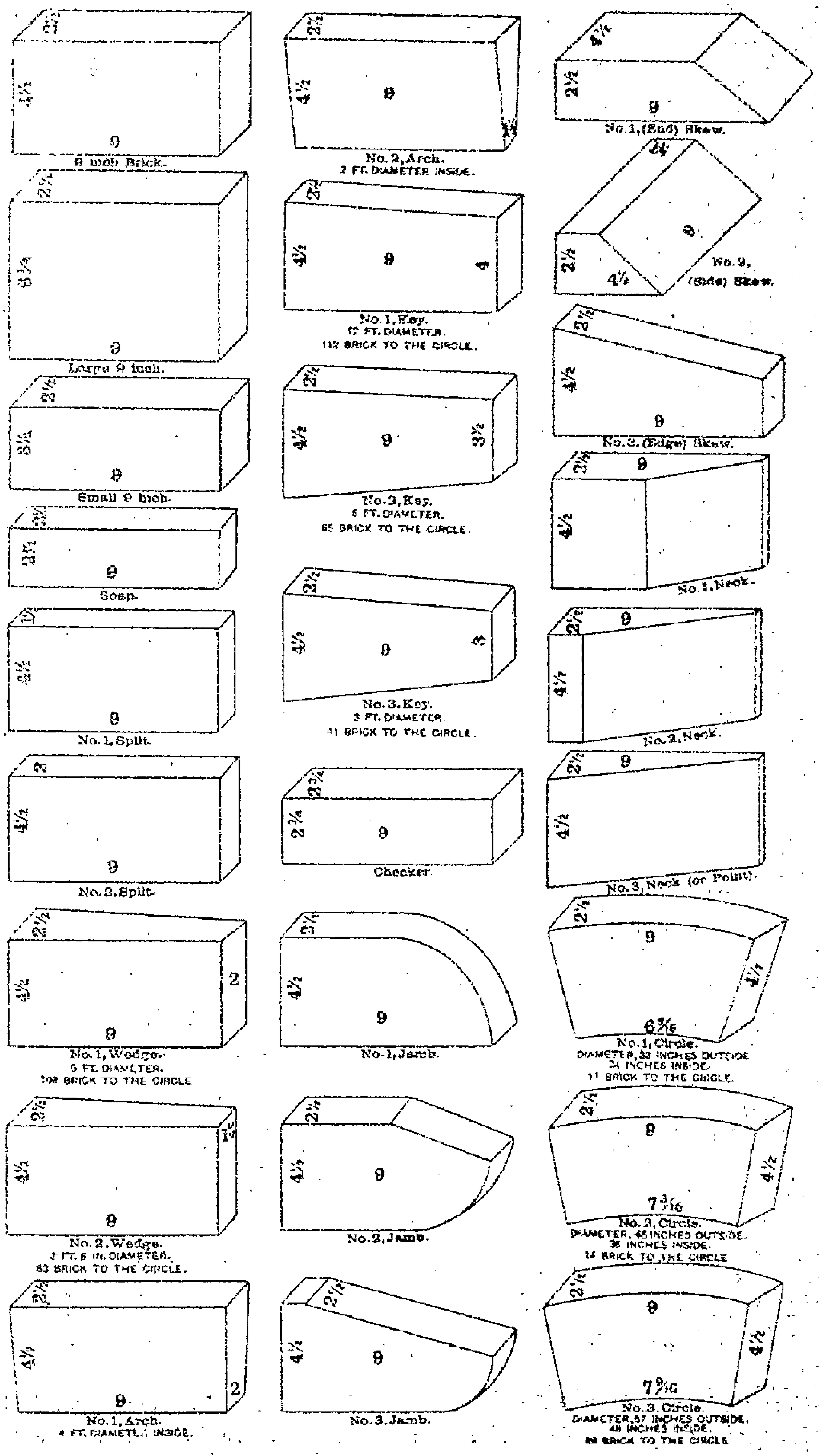
Fire-brick Shapes.—The wants of consumers of fire-brick demand an improved form in presenting the lines of goods carried by manufacturers, and to meet this demand there will be found illustrated in Figs. 92 to 101, shapes carried in stock by the well-known firm of Messrs. Fredericks, Monroe & Co., Farrandsville, Pa., from whose catalogue the illustrations are selected.

*Refractory Brick-Work of Blast-Furnaces, and its Preservation.**—Blast-furnaces are large gas generators, in which the gases generated reduce the iron ore and carbonize the iron thus produced, whilst the heat liberated by the gasification of the carbon melts the crude iron and the accompanying constituents of slag, the latter being presently separated from the crude iron. In these few words is expressed the diversity of objects the blast-furnace has to serve. It will, however, be seen later on, that besides the above-mentioned processes, many other chemical processes take place in the blast-furnace. Moreover, a blast-furnace has to be worked day and night for many years in succession, so that there is but little opportunity for thorough repair of damages.

On the other hand, a kiln, for instance, has to serve but one purpose, and hence its interior can every few days be thoroughly inspected and, if necessary, repaired. Moreover, the

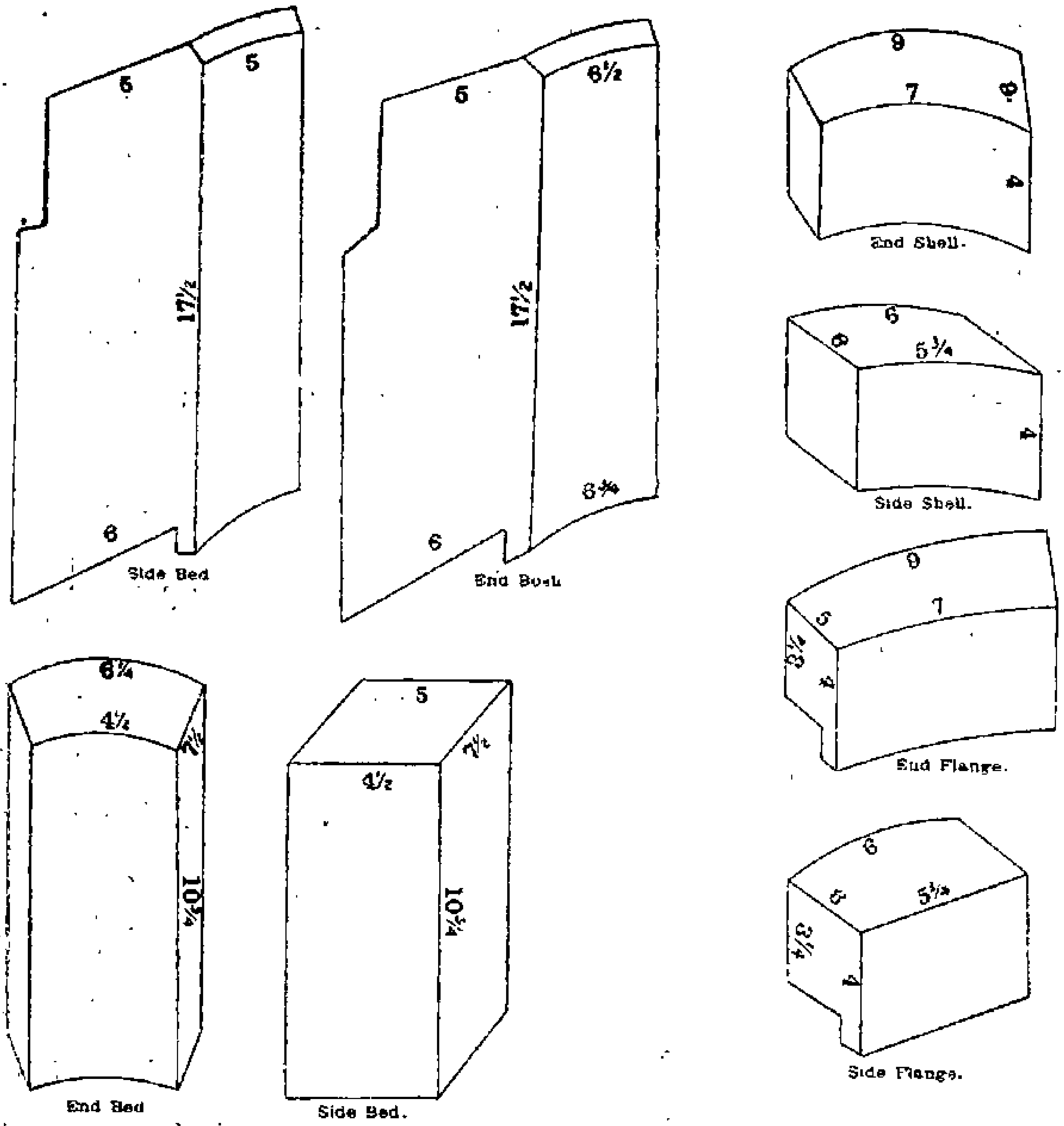
* Address before the general meeting of the Association of German Manufacturers of Refractory Materials, in Berlin, February 24th, 1892. By Fritz W. Lürmann.

Fig. 92.

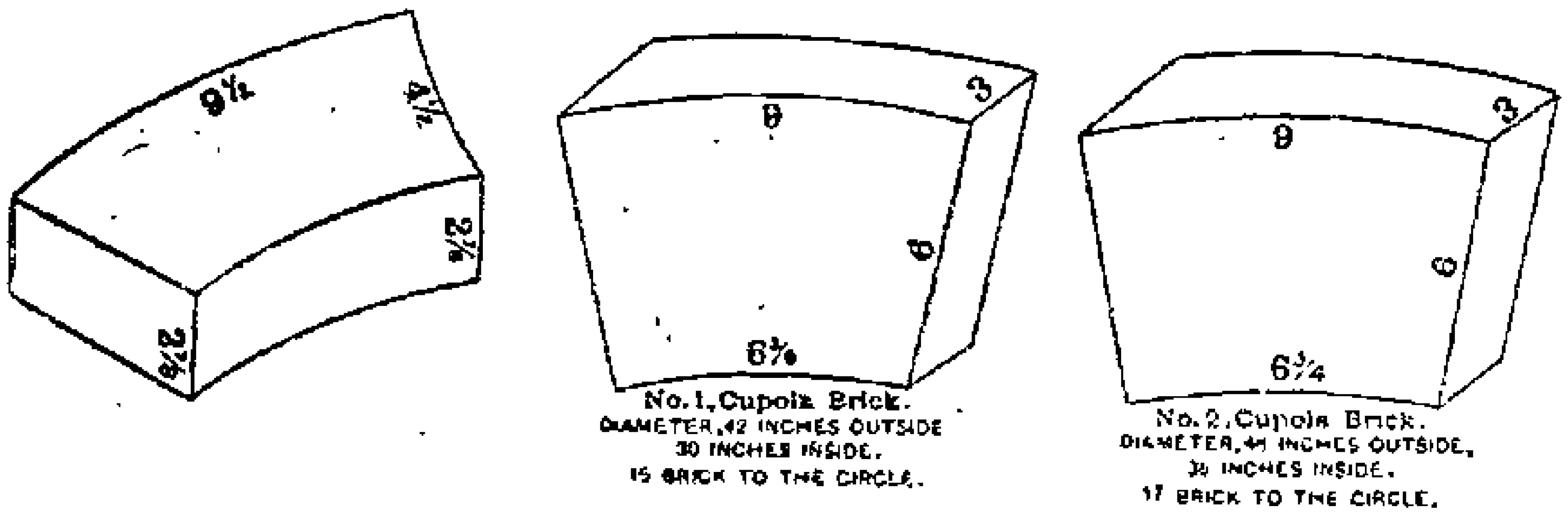


NINE-INCH SHAPES.

FIG. 93.

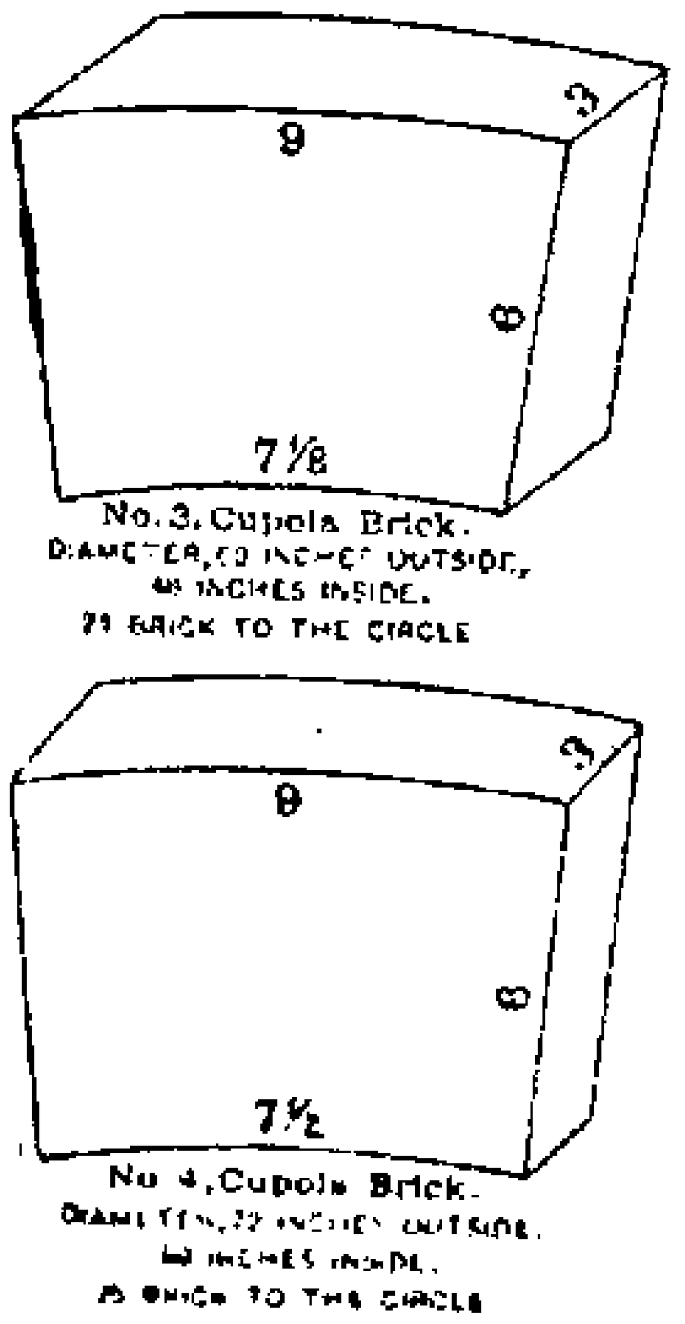


M'KENZIE CUPOLA SHAPES.



Diameter, 30 inches inside, 39 inches outside.

"	36	"	"	45	"	"
"	42	"	"	51	"	"
"	48	"	"	57	"	"
"	54	"	"	63	"	"
"	60	"	"	69	"	"
"	66	"	"	75	"	"
"	72	"	"	81	"	"



CUPOLA BLOCKS.

arrangement and producing capacity of the blast-furnace have for the last forty years been constantly changed. The first coke blast-furnace in Westphalia was built forty-three years ago, but the size and arrangements of those blast-furnaces cannot be compared with the present ones.

A daily out-put of 40,000 pounds of pig-iron was at that time considered something enormous, whilst the present blast-furnaces of the different German iron districts produce on an average ten times that quantity.

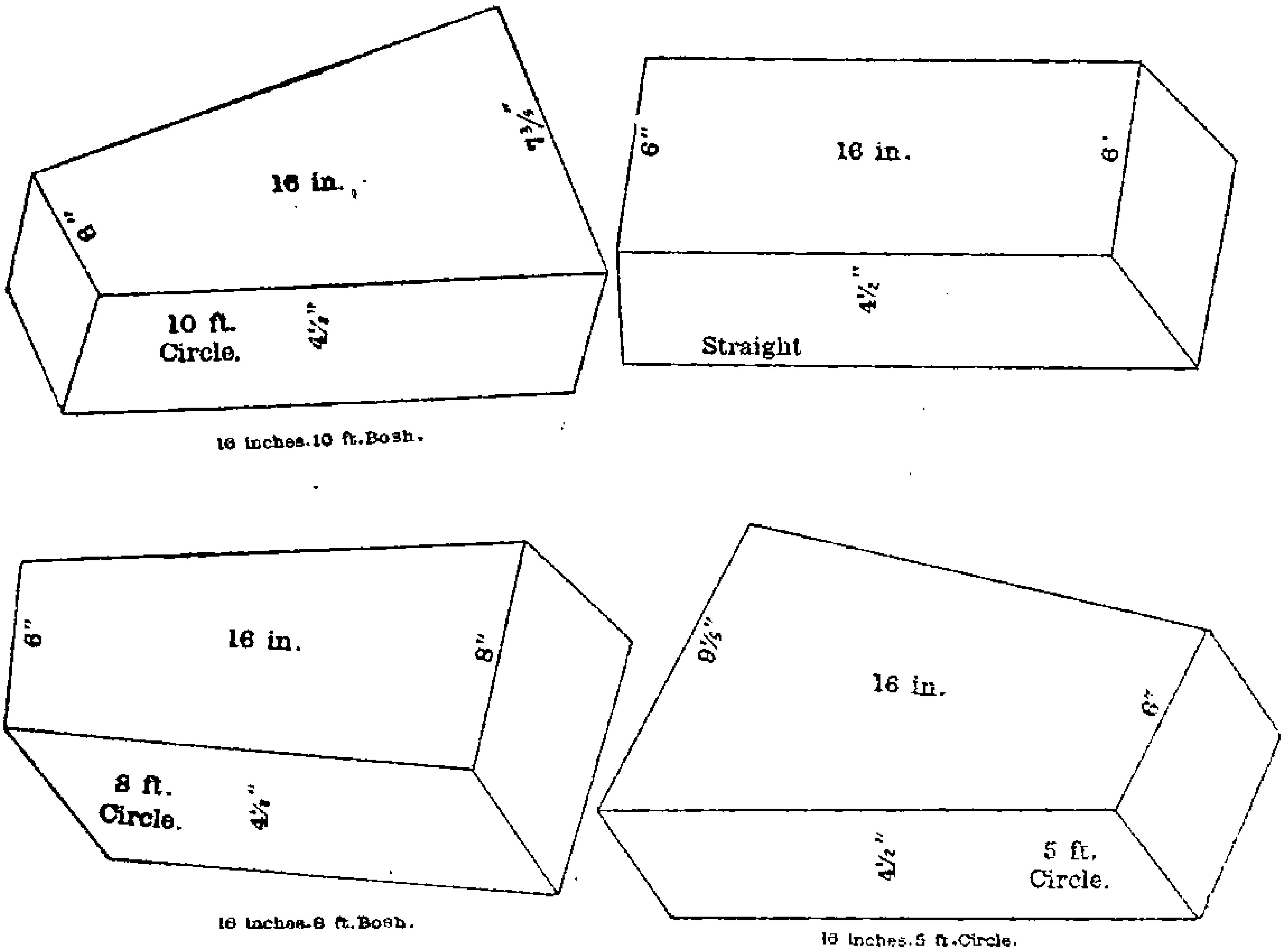
The various purposes which a blast-furnace has to serve, the many chemical processes which take place in it, and the long-continued and enormously increased work expected from it, will sufficiently explain the difficulties of procuring a refractory material for the brick-work which will answer all demands. In regard to blast-furnaces, the term "refractory," as generally applied to brick, means a great deal more. The exposure of a so-called refractory material to the action of heat alone is something entirely different from its being at the same time exposed to various other influences. Now, in the blast-furnace, besides heat, slag and other hot liquid and gaseous combinations, simultaneously exert a dissolving influence upon the refractory material.

Thanks to the constant improvement in the manufacture of refractory material, there is no difficulty in procuring brick capable of resisting the highest degree of heat at present attainable. But as regards resistance against the dissolving influences upon the brick-work of the blast-furnace, there is no material known at the present time which can successfully withstand these influences.

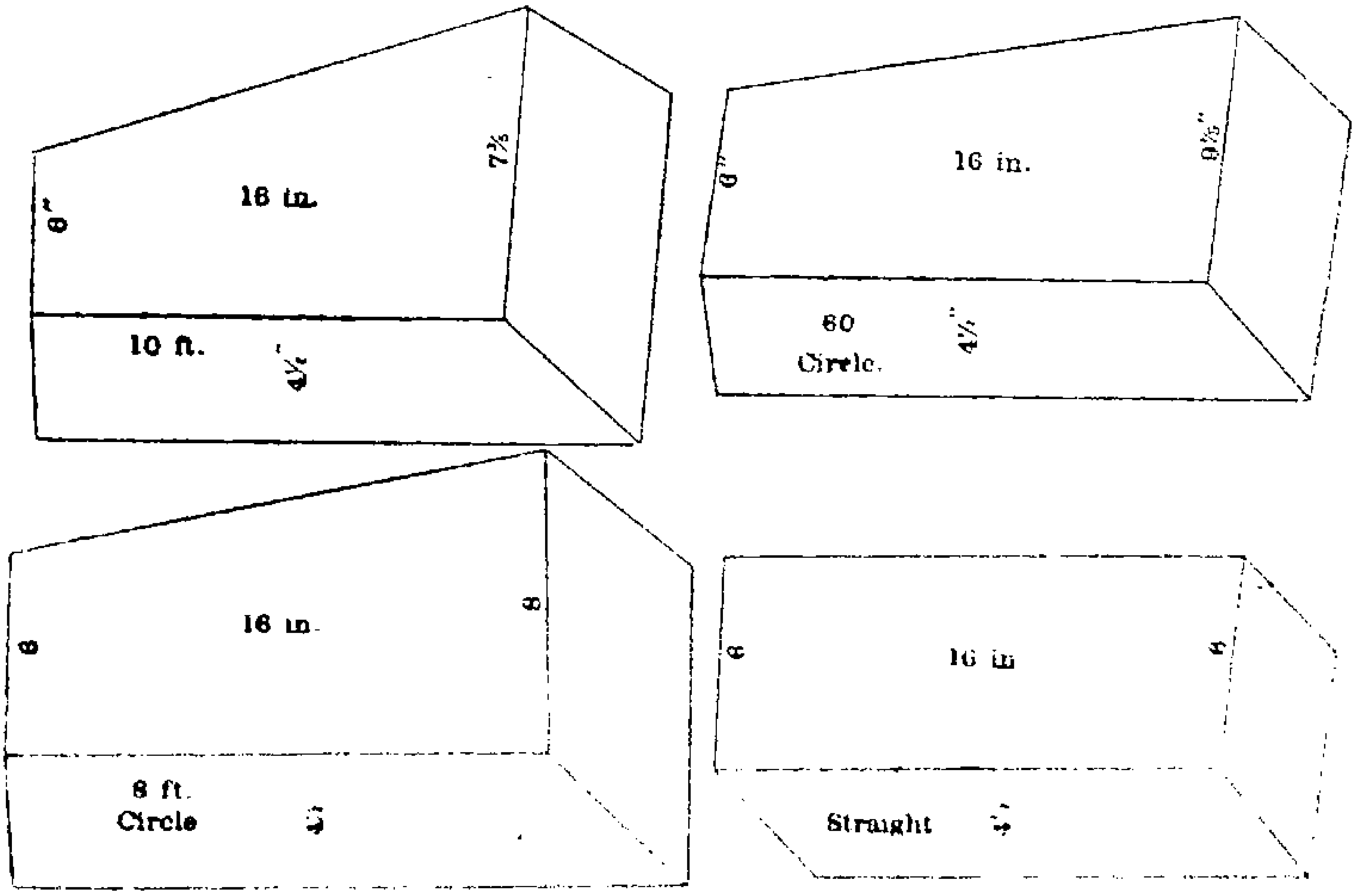
Quartz, as well as the best refractory brick, withstands the dissolving action of slag, etc., as little as ordinary brick, because the principal constituents—silica and alumina—of all these materials are with avidity dissolved by the slag, no matter in what proportions to one another they may occur in them. The dissolution may be slightly retarded if the brick possesses great density—hence mechanical strength—without brittleness. But

dense or loose, all so-called refractory brick are finally dissolved, just as sure as sugar is in coffee.

FIG. 94.



BLAST-FURNACE BOSH.



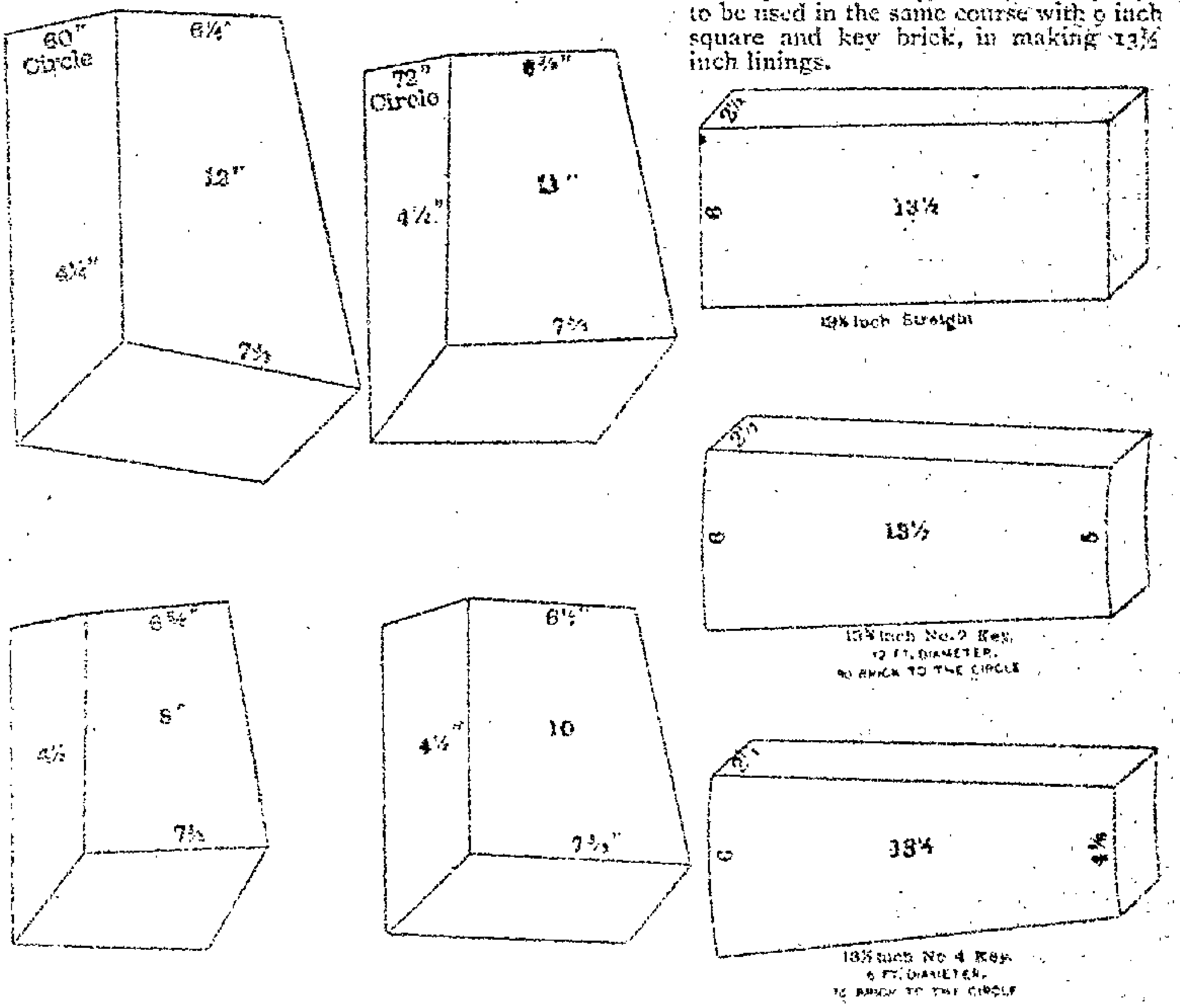
BLAST-FURNACE LININGS.

That a material need not be refractory according to the ordinary understanding of the term in order to resist the dissolving action of the slag, etc., is proved by the use of carbon brick.

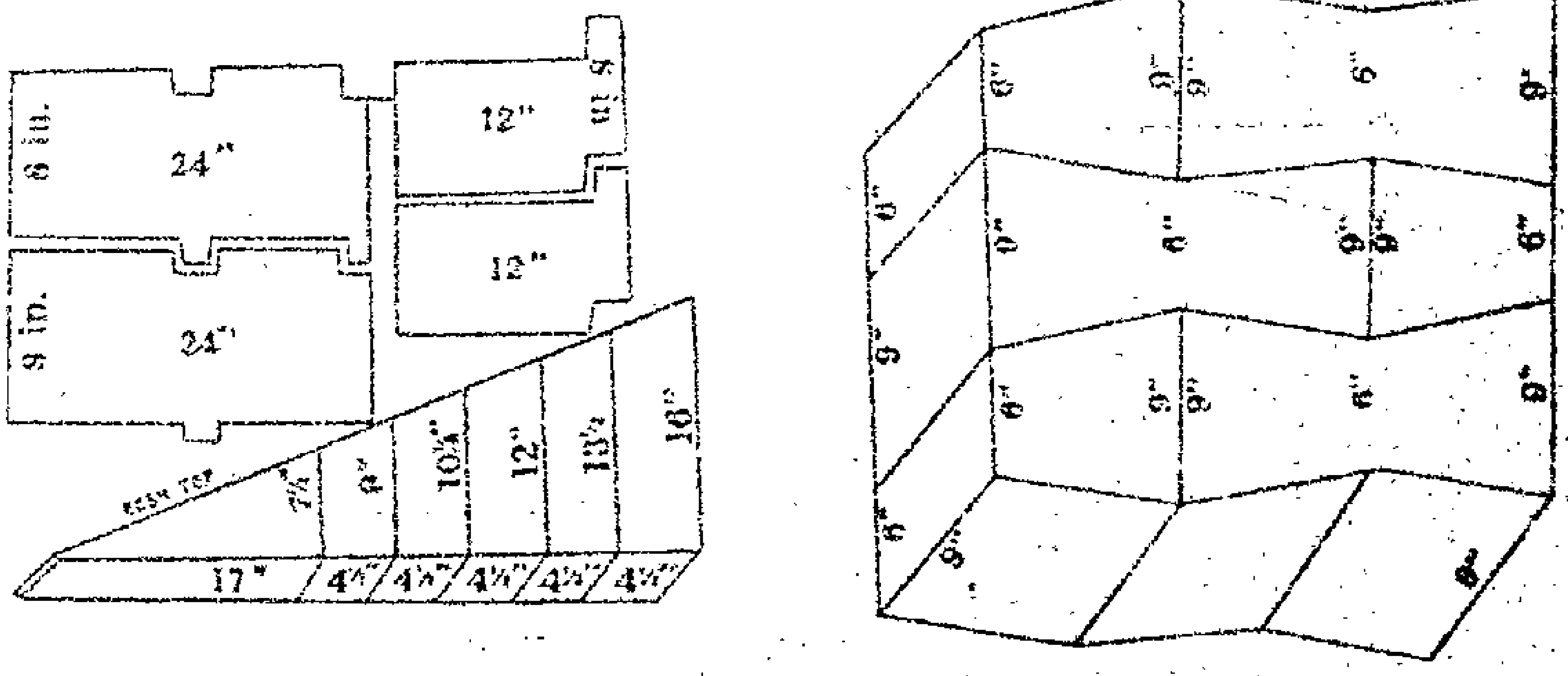
FIG. 95.

13½-INCH BLAST-FURNACE LINING BRICK.

They are made 2½ inches thick, so as to be used in the same course with 9 inch square and key brick, in making 13½ inch linings.



BLAST-FURNACE LININGS.



BLAST-FURNACE BOTTOMS.

The best means of preserving the walls of blast-furnaces without regard to the material used in their construction is to cool them with water.

The carbon brick, which have now been largely introduced, have, since 1876, been used in France for constructing the walls of the hearths of blast-furnaces, and at first appeared to be very suitable for that purpose.

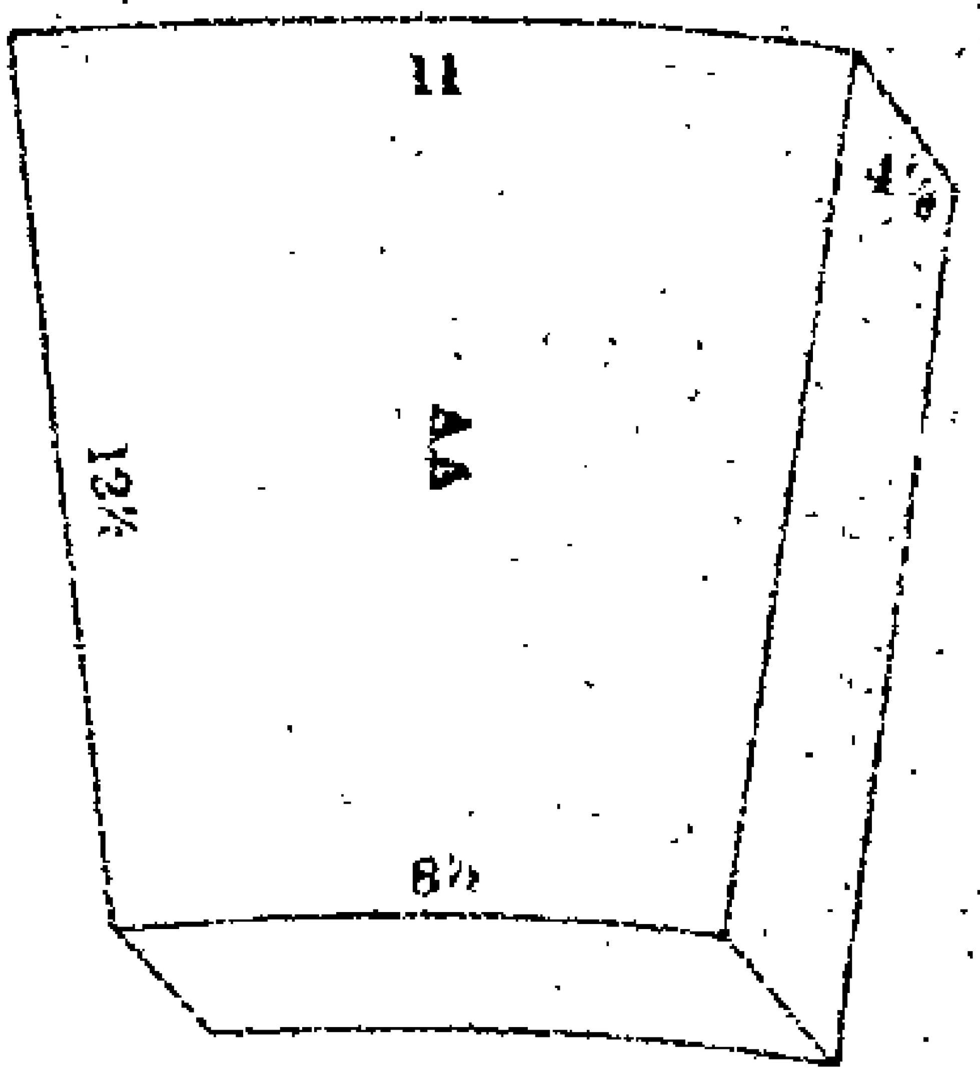
These carbon brick are not dissolved by the slag, and if the latter alone were present in the hearth of a blast-furnace, they would prove to be of great durability.

However, in the hearth, and always upon the bottom of it, is also the crude iron. Now, in the blast-furnace, iron is produced which is not yet saturated with carbon, and, therefore, absorbs the latter with avidity when it comes in contact with coke, and, hence, also when in contact with the carbon-brick.

By the solution of their carbon, these carbon-brick are, of course, destroyed, and this is the reason that many bottoms of blast-furnaces, as well as the lower portions of the hearth, constructed of carbon-brick, are rapidly dissolved. Hearth-bottoms constructed of carbon-brick have shown the least durability, whilst the same material, when used for the portions of the walls of the hearth and of the boshes which do not constantly come in contact with the liquid iron, is apparently quite durable. However, since carbon-brick have been in general use for a short time only, experiences in regard to the latter subject are not sufficient to allow of a final judgment. Formerly, when blast-furnaces were worked more slowly, only the refractory brick-work of the hearth was dissolved, but in consequence of the constantly increasing demands made on the blast-furnaces by working with the introduction of more and hotter blast, the dissolution first extended to the boshes and lately even to the refractory brick-work of the stack.

Cooling with water being the only means known at present for preserving the brick-work of blast-furnaces, not only the hearth, but also the boshes, and in recent times, the stack as well are cooled.

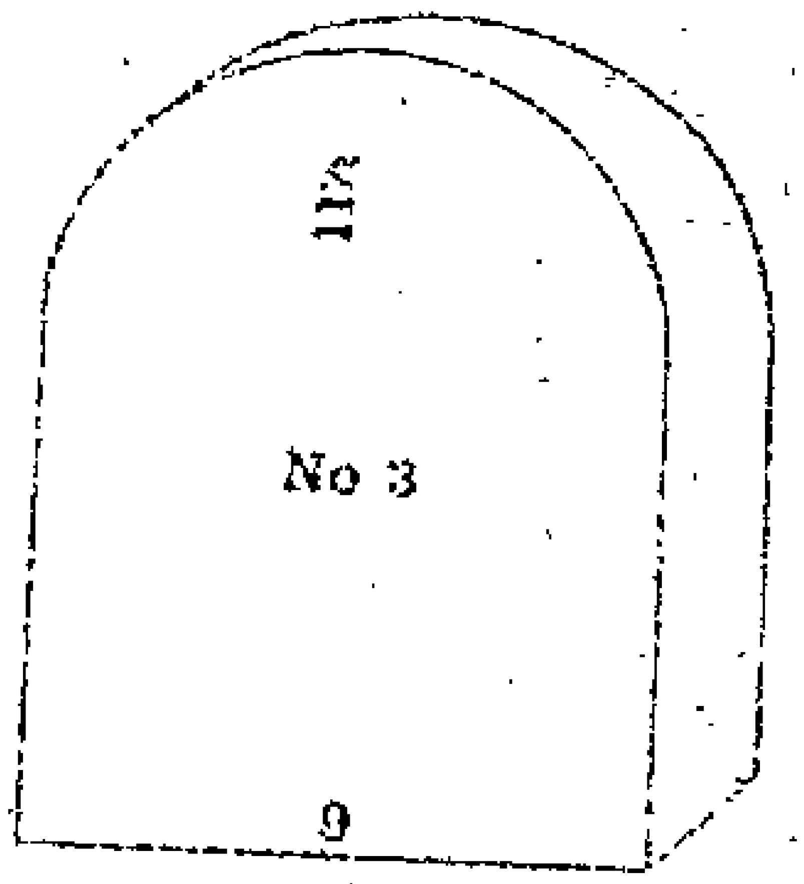
FIG. 96.



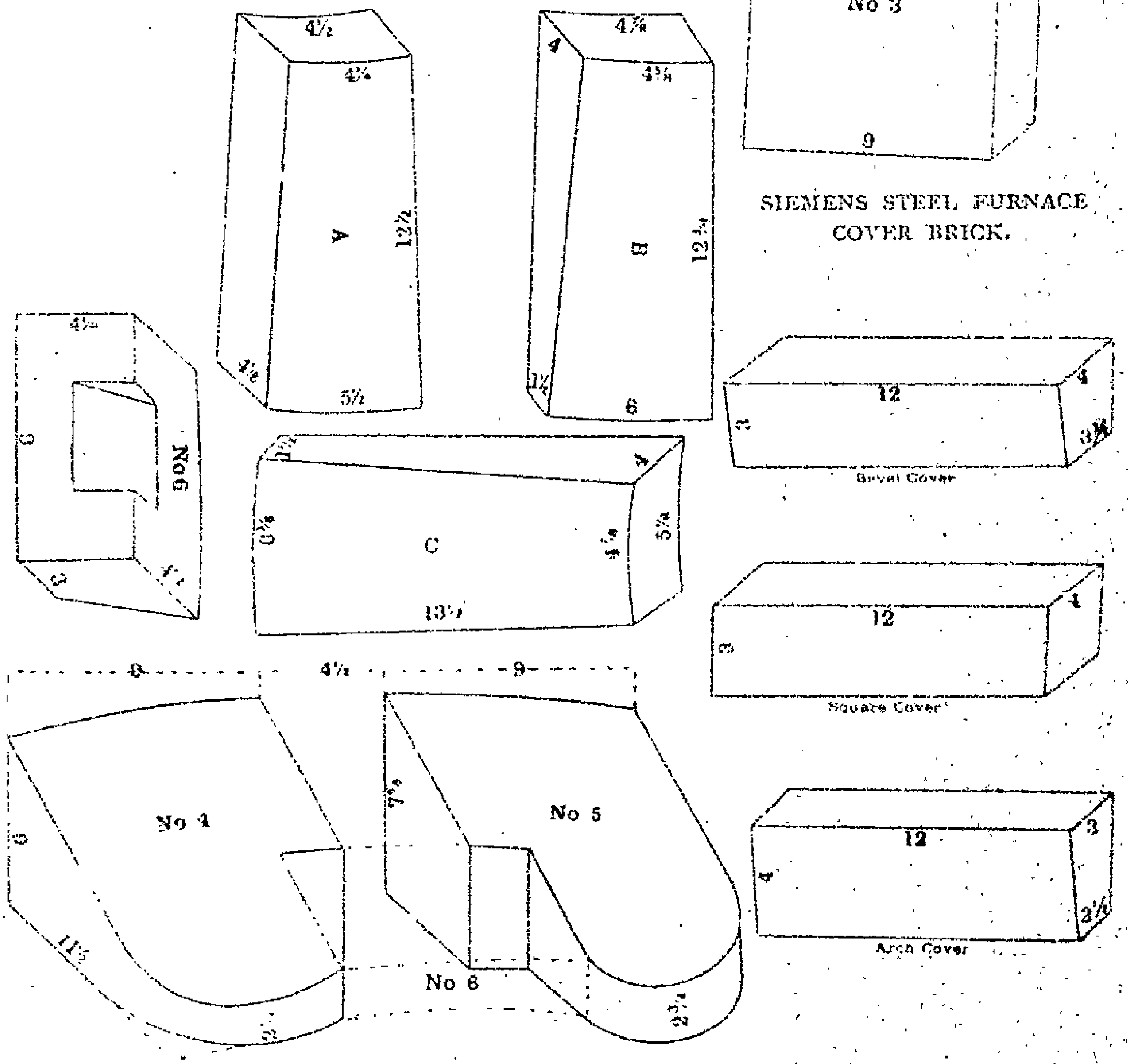
SIEMENS CRUCIBLE STEEL MELTING FURNACE.

List of Shapes required for one 6-pot furnace.

No. A A	4	pieces.
No. A	26	"
No. B	18	"
No. C	16	"
No. 3	12	"
No. 4	2	"
No. 5	2	"
No. 6	2	"



SIEMENS STEEL FURNACE COVER BRICK.



SIEMENS HEATING FURNACE BLOCKS.

It is not necessary to discuss here the cause of the great wear of certain portions of the stack of a blast-furnace in which ferro-manganese is produced, the production of the latter being a limited one. As causes of the rapid wear of the brick-work of the stacks of blast-furnaces in general, from a height of several meters to a few millimeters towards the exterior, must be mentioned:

1. Abrasion by the downward passage of the charge.
2. The action of constituents of blast-furnace gases, for instance, cyanogen and its salts.
3. Melting off by common salt, which is contained in coke.
4. Cracking by separations of carbon and carbonic acid caused by iron particles which are formed from iron disulphide (FeS_2) in the refractory brick.

Of the above-mentioned causes, either one or all may act upon the brick of the stack of a blast-furnace.

Ad. 1. With the present improvements, it is not difficult to produce refractory brick which will resist abrasion by the downward passage of the charge. Hence, this cause need only in exceptional cases be taken into consideration for explaining the rapid wear of the brick-work of blast-furnace stacks.

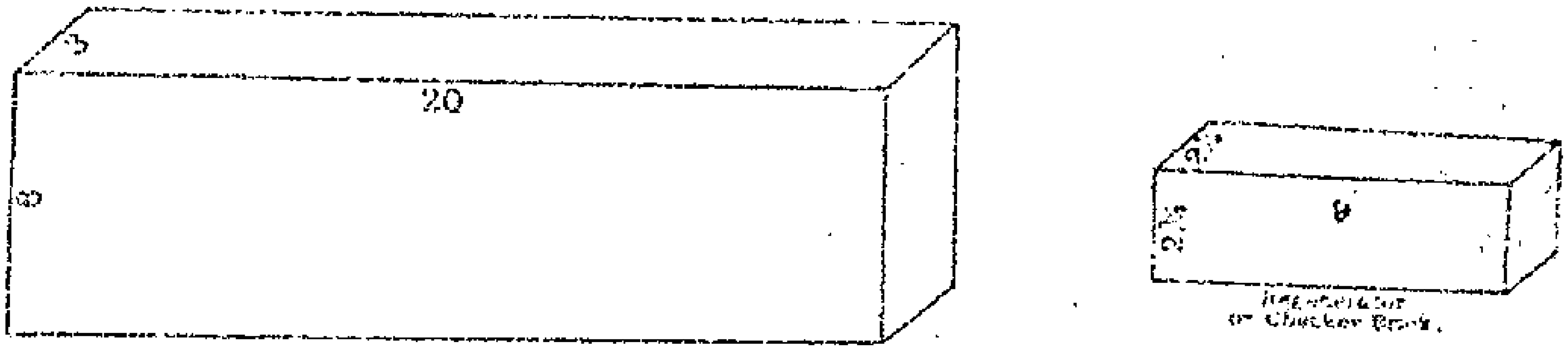
Ad. 2. It is a well-known fact that blast-furnace gases contain much cyanogen. The formation of it in the blast-furnace is much faciliated by the occurrence of nitrogen together with carbon in coke. By coking Westphalia coals in coke-ovens or gas-retorts, 31 to 36 per cent. of their nitrogen remains, according to Dr. Knoblauch, in the coke; 1.5 to 2 per cent. of the nitrogen passes over as cyanogen, whilst 1 to 3 per cent. of it is found in the tar, and 10 to 14 per cent. of it in the ammonia.

One cubic meter (1.308 cubic yards) of the top-gas of a modern blast-furnace contained 1.97 to 6.6 grammes (30.4 to 101.85 grains) of cyanogen, whilst the gases from the melting-zone were still richer in it.* One ton of coke yielding about 4733 cubic meters of gas, the amount of cyanogen produced

* These analyses were made in the laboratory of the Clarence Iron Works, Middlesborough, England.

from it in the blast-furnace would be from 8.48 to 31.23 kilogrammes (18.65 to 68.7 lbs.). Hence a blast-furnace with a daily consumption of but 100 tons of coke would produce 848 to 3.123 kilogrammes (1865.6 to 6870.6 lbs.) of cyanogen.

FIG. 97.



SIEMENS REGENERATOR TILE AND BRICK.

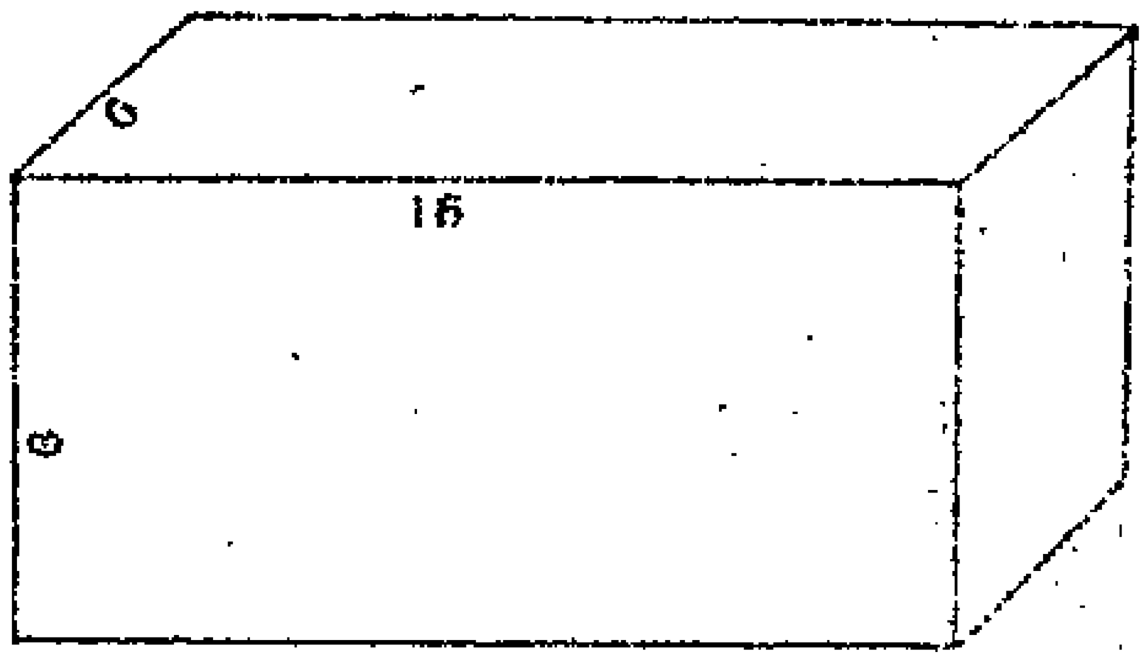
The following sizes are kept in stock:

16 x 6 x 3.	22 x 6 x 3.
18 x 6 x 3.	24 x 6 x 3.
19 x 6 x 3.	24 x 9 x 3.
20 x 6 x 3.	26 x 9 x 3.
21 x 6 x 3.	

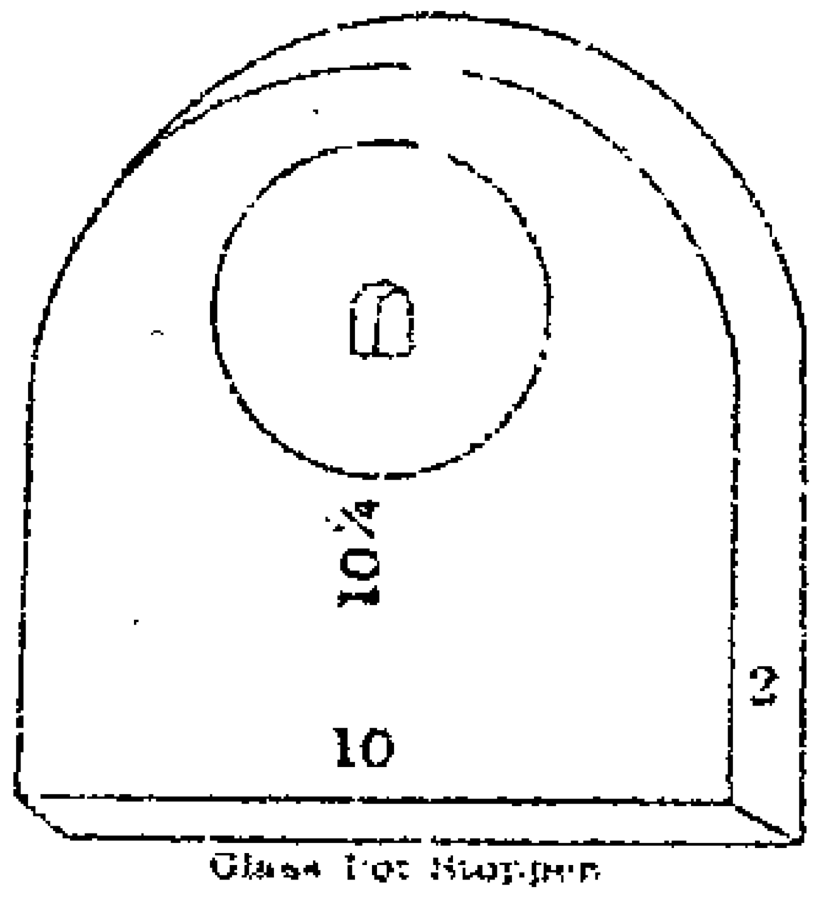
All other sizes are usually made to order.

It is customary in large works to keep an ample stock of checker brick always on hand to meet all orders.

All sizes are usually made to order.



All sizes are usually made to order.



All sizes and styles are usually made to order.

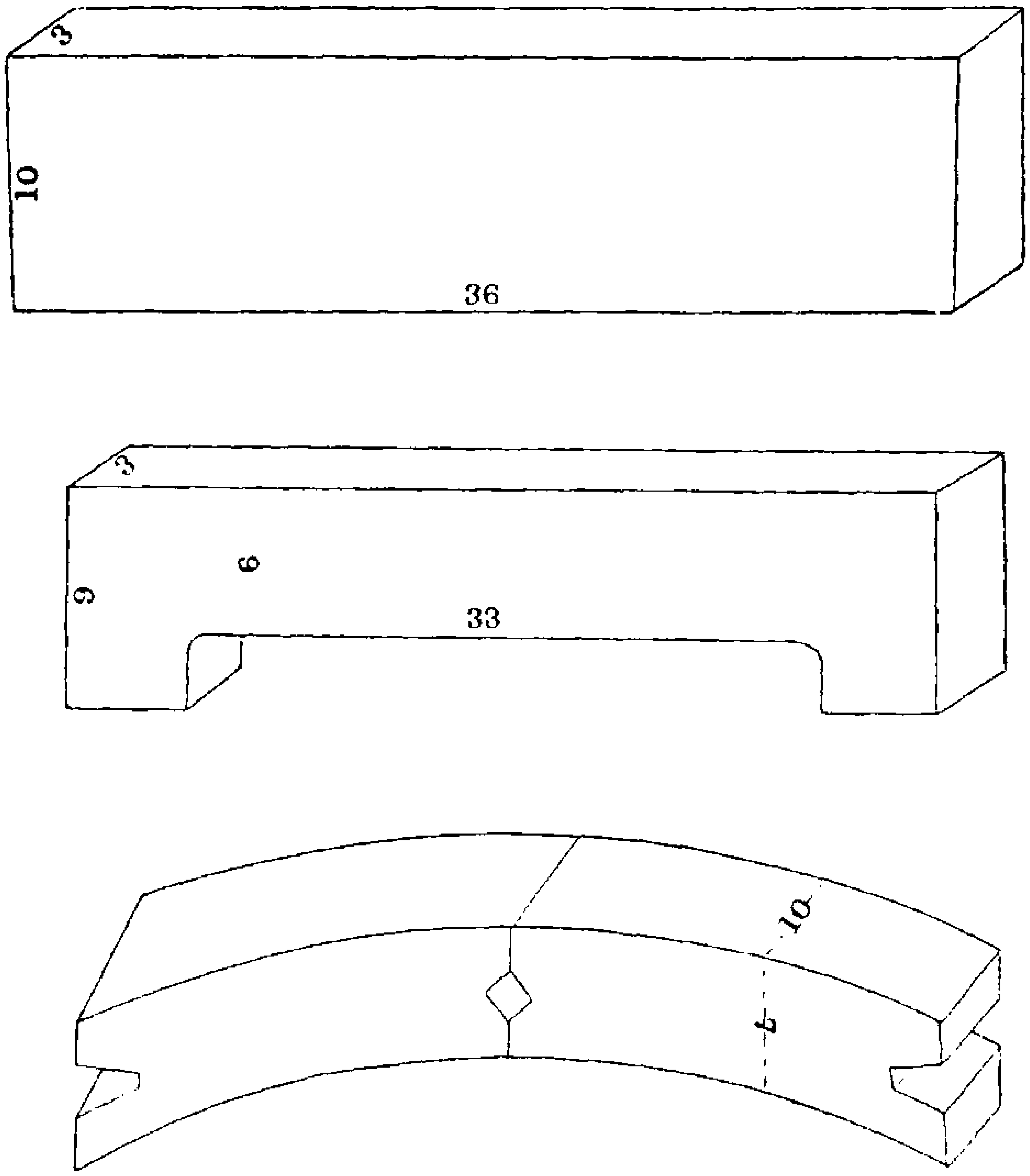
GLASS-FURNACE BRICK.

These immense, and therefore improbable, quantities of cyanagon, in connection with alkalies or alkaline earths, and

perhaps also with volatile metals, would suffice to explain the rapid wear of all parts of the refractory brick above the melting zone of the blast furnace. In the refractory clays, which are products of the decomposition of feldspathic minerals, alkalies generally occur.

Whether the cyanogen in the blast-furnace gases is capable

FIG. 98.



LOCOMOTIVE FIRE-BOX ARCHES.

of withdrawing, at the temperatures prevailing in the stack of a blast furnace, alkalies from the refractory brick, and thus to decompose them, would have to be determined by experiments. It is, however, an established fact that parts of the cast iron of the apparatus for collecting the waste gases as well as of the iron

used as a support of the top of the furnace are frequently completely corroded by the constituents of the blast-furnace gases.

It has not yet been determined whether cyanogen in the blast-furnace gases is capable of withdrawing alkalies and earths from the materials of the charge, and in the form of cyanide of potash or volatile cyanide exerting a destructive effect upon the refractory brick. Large quantities of cyanide of potash are dissolved from the walls of blast-furnaces by the cooling water, and fused salts of cyanogen also drip frequently from the joints of the walls.

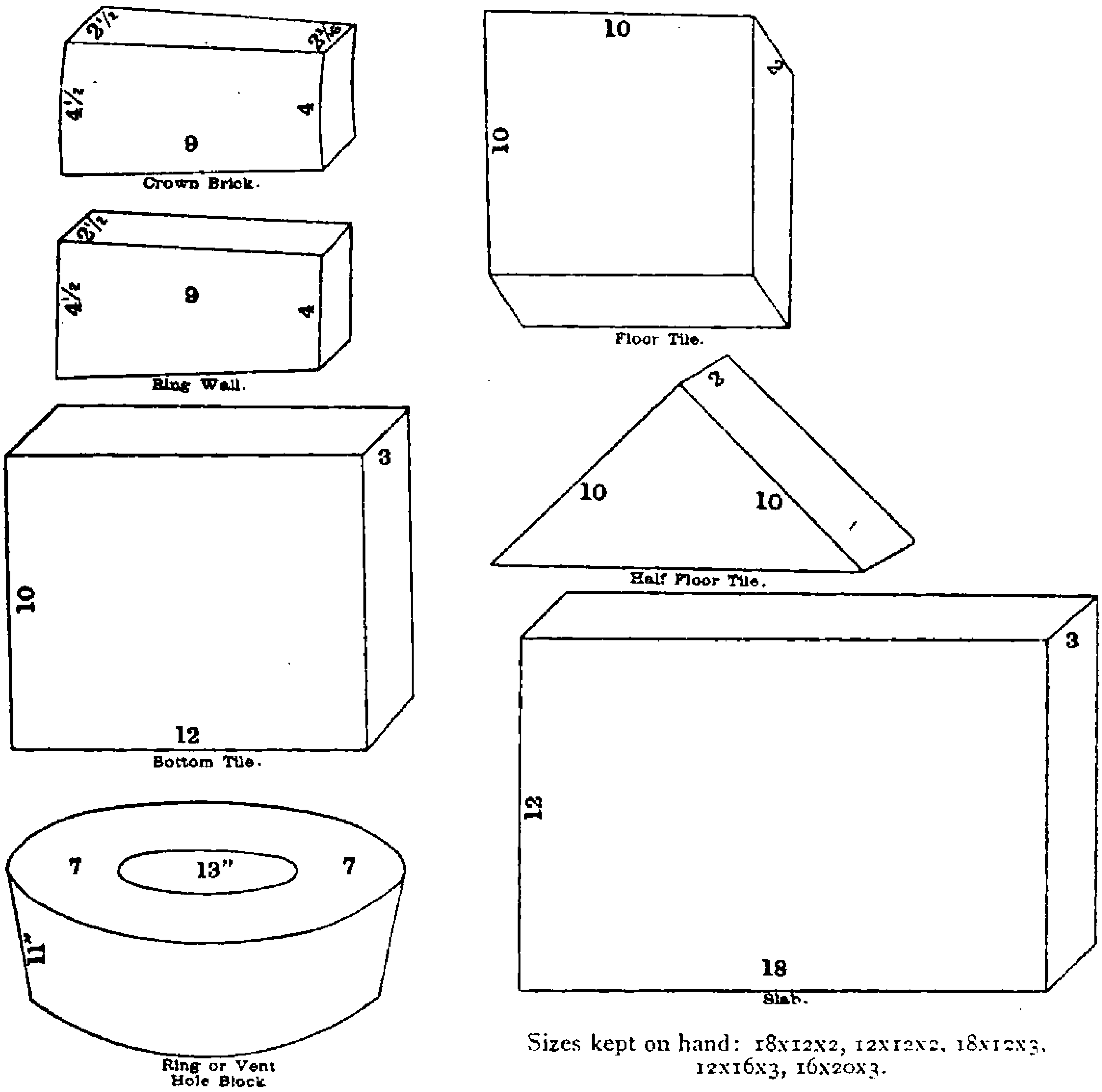
Ad. 3. As is well-known, the coal-measures contain springs strongly impregnated with common salt, and hence the latter is frequently found also in the coal. According to experiments made in 1884, a charge of 6,000 kilogrammes (13,200 lbs.) of coal of a coke-oven contained 1.8 kilogrammes (3.96 lbs.) of common salt; another charge of the same quantity of coal, 3 kilogrames (6.6 lbs.), and one as much as 22 kilogrammes (48.4 lbs.). Common salt is volatile; it partially evaporates in coking the coal, and in coke ovens, worked without gaining the by-products, it, together with the hot products of combustion of the gases—hence at a white heat—comes in contact with the hot refractory brick, and, by the silica of the latter, is decomposed to sodium and chlorine.

The sodium combines with the silica and alumina of the refractory brick to a liquid slag, which drops off. In consequence of the development of chlorine the brick acquires a spongy appearance. An analysis of such brick showed a content of 7.17 per cent. of sodium. The brick of the walls of such coke ovens are completely dissolved by this action. Large quantities of free chlorine are contained in the gases of coke-ovens.

This destruction of coke-ovens has caused many losses. With coke-ovens, where the by-products are gained, the content of salt in the gases is not injurious. However, a portion of the salt remains in the coke, and according to recent experiments, the different cokes used in the blast-furnaces of a large

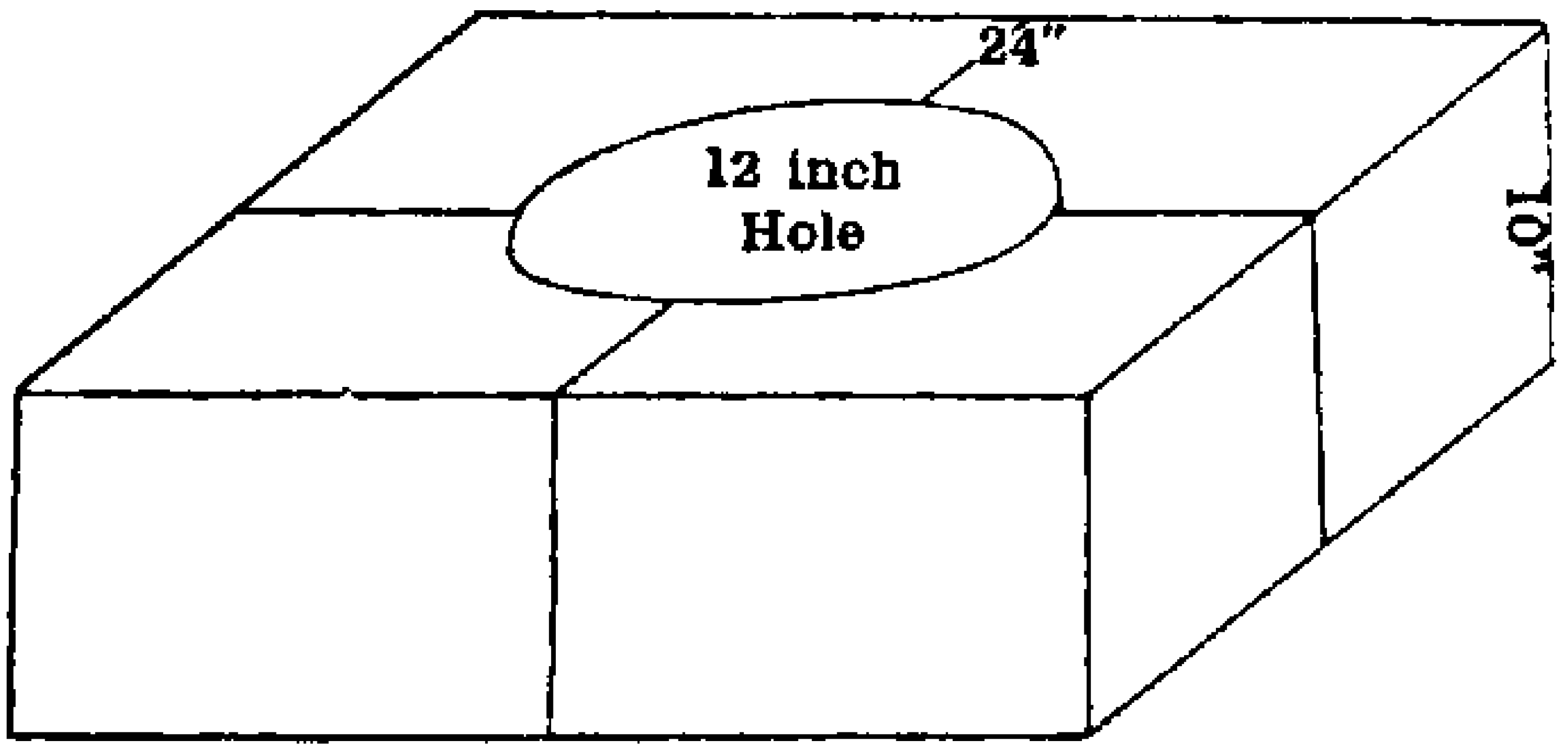
concern contained, on an average, 0.181 per cent. of salts soluble in water, namely: 0.062 per cent. of sodium sulphate (Na_2-

FIG. 99.



Sizes kept on hand: 18x12x2, 12x12x2, 18x12x3, 12x16x3, 16x20x3.

COKE-OVEN BRICK AND TILE.



Feed-Holes for use in Saw-Mills and Tanneries: 12 and 16 inch hole kept in stock.

FEED-HOLE BLOCKS.

SO_4), and 0.119 per cent. of common salt (NaCl). According to this, 62 kilogrammes (136.4 lbs.) of sodium sulphate, and 119 kilogrammes (261.8 lbs.) of common salt are introduced into a furnace consuming only 100 tons of coke per day. As is well known, common salt is used for glazing vessels of clay and stoneware.

If now the refractory brick of the walls of blast-furnaces are constantly exposed to the action of such large quantities of salt, and hence become glazed, they will just as well wear out in a few months as those of the coke-ovens.

Ad. 4. In most beds of the best refractory clays occur pyrites which, at higher temperatures, are converted into ferrous sulphide; the latter by the gases of the blast-furnace is converted into metallic iron.

With this metallic iron the gases of the furnace, in which large quantities of carbonic oxide occur, remain in further contact. By the contact with the metallic iron the carbonic oxide is decomposed to carbon and carbonic acid, the carbon depositing upon the surface of the small iron balls and forming a shell around them. Notwithstanding this shell of carbon, new carbonic oxide gases constantly penetrate to the iron, fresh carbon being always deposited upon the latter.

The very minute balls of iron are thus gradually surrounded with an envelope of carbon the size of a pea and a hazel-nut. Nothing, and least of all the refractory brick of the furnace, can withstand this gradually augmenting separation of carbon; the brick being thereby cracked and completely destroyed.

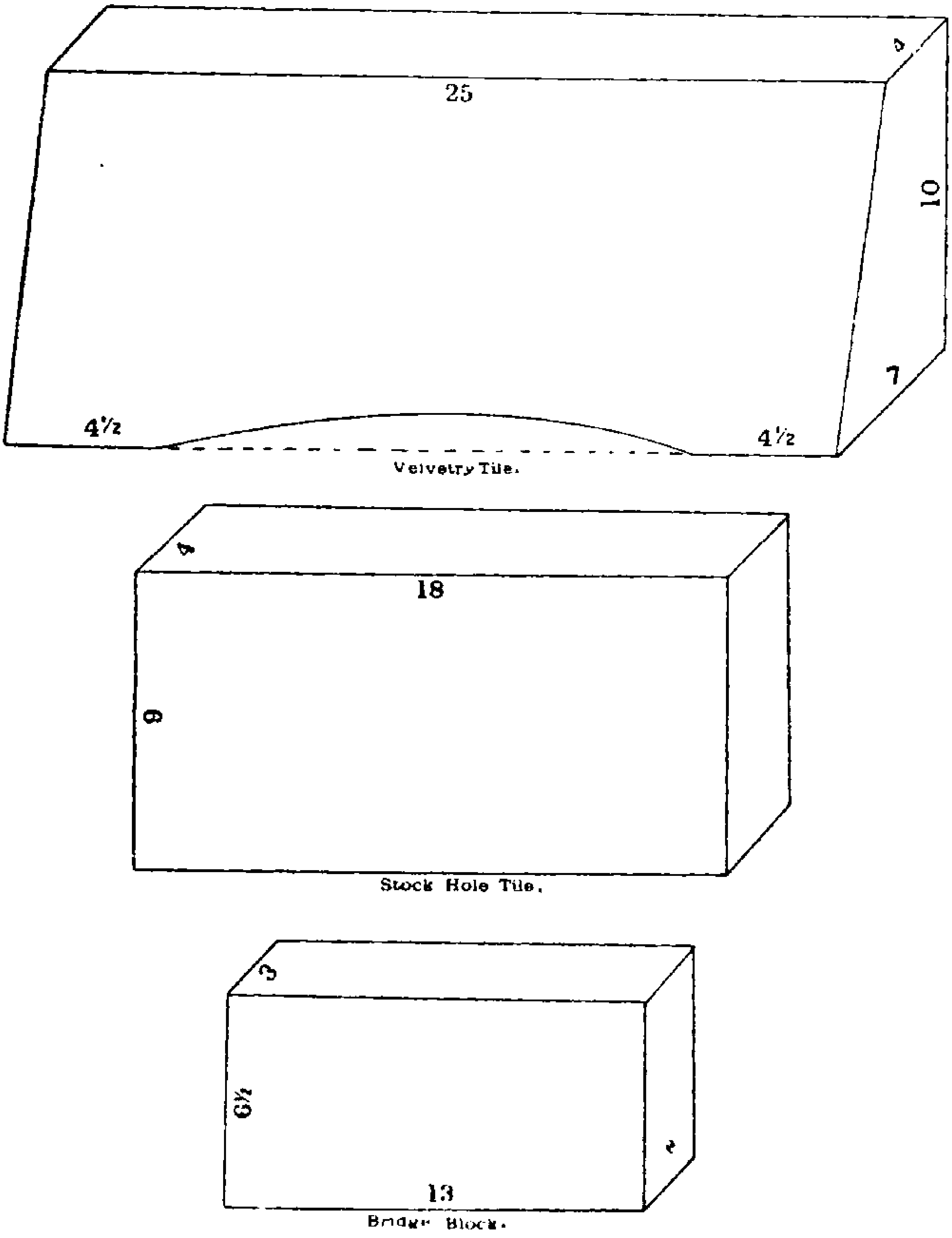
The brick-work of blast-furnaces, if constructed of carbon brick, would not be exposed to the three last-mentioned causes of destruction. Carbon brick are now made without the addition of clay, etc. They possess a considerable degree of hardness and solidity, so that they would oppose considerable resistance to abrasion by the downward passage of the charge. They may also be used not only for the boshes but also for the stack.

Carbon Deposits in Fire Brick. (Written for the *Engineer-*

ing and Mining Journal by A. D. Elbers.) The following extract from a recent essay on "The causes of the destruction of fire-brick in blast-furnace linings," *Stahl und Eisen*, March 15th, 1892) is noteworthy:

Cause No. 4.—Bursting, from the formation of carbon de-

FIG. 100.



ROLLING-MILL TILES.

posits, within the brick, on particles of iron derived from pyrites.

This hypothesis—analogous to that of lumps of ore bursting in the blast furnace by reason of their impregnation with deposited carbon—is accounted for as follows: "The ferric disulphide (pyrites) changes at elevated temperatures to ferrous sulphide, the latter is changed by the blast-furnace gases to to metallic iron, and on this iron the carbonic oxide gas, in permeating the brick, deposits carbon according to the reaction: $2CO = CO_2 + C$. The particles of iron, which are quite diminutive, thus become coated with carbon, and this deposition continues until the coated particles grow to lentil, pea, or even to hazel-nut size, and then—burst the brick!"

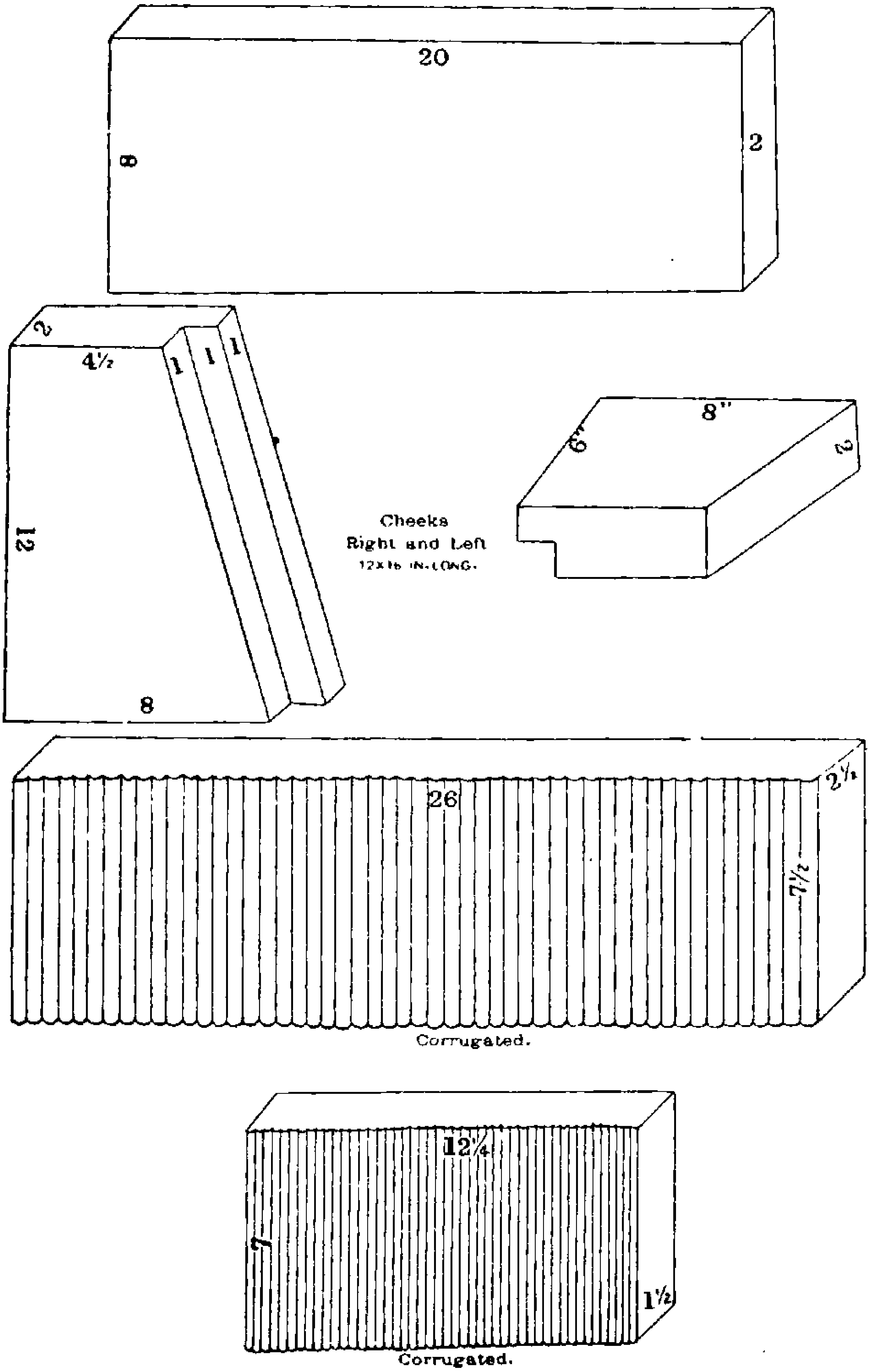
The assumed but undefined reaction by which the gas-furnace gases are supposed to "change" ferrous sulphide to metallic iron, serves, in this instance, to support an apparently fallacious theory; for at the temperature at which FeS or Fe_7S_8 can lose the remainder of their sulphur, no deposition of carbon takes place. In other words, if the brick in any particular spot of the furnace is hot enough to render the complete oxidation of the sulphur possible, then that brick is too hot for the carbonic oxide gas that enters its interstices to split up into carbonic acid gas and solid carbon.

Nevertheless, deposits of the latter do form in the brick linings of blast-furnaces, where the brick is not too hot. These formations must, however, *not* be ascribed to the presence of converted pyrites, *but* to particles of iron derived from the ferric hydrate obtained in the clay, or, also, to chips from the crusher in which the clay was ground. That the accumulations of carbon on these particles cannot increase to the extent of exerting a "breaking" strain on the brick in which they are lodged is almost self-evident, because the pressure which they exert within the brick cannot be greater than that of the air or gases inside the furnace, and also because the deposited carbon is of no greater density than the brick components are. Nor is there such a difference in the coefficients of expansion of impregnated carbon and brick substance as to render it possible that the carbon should expand at an increased temperature

sufficient to burst the brick, or that the brick should break at a lower temperature on account of the unequal contraction of the respective substances.

But what can happen very frequently is, fire-brick bursting

Fig. 101.



TILE FOR FIRE-PLACES.

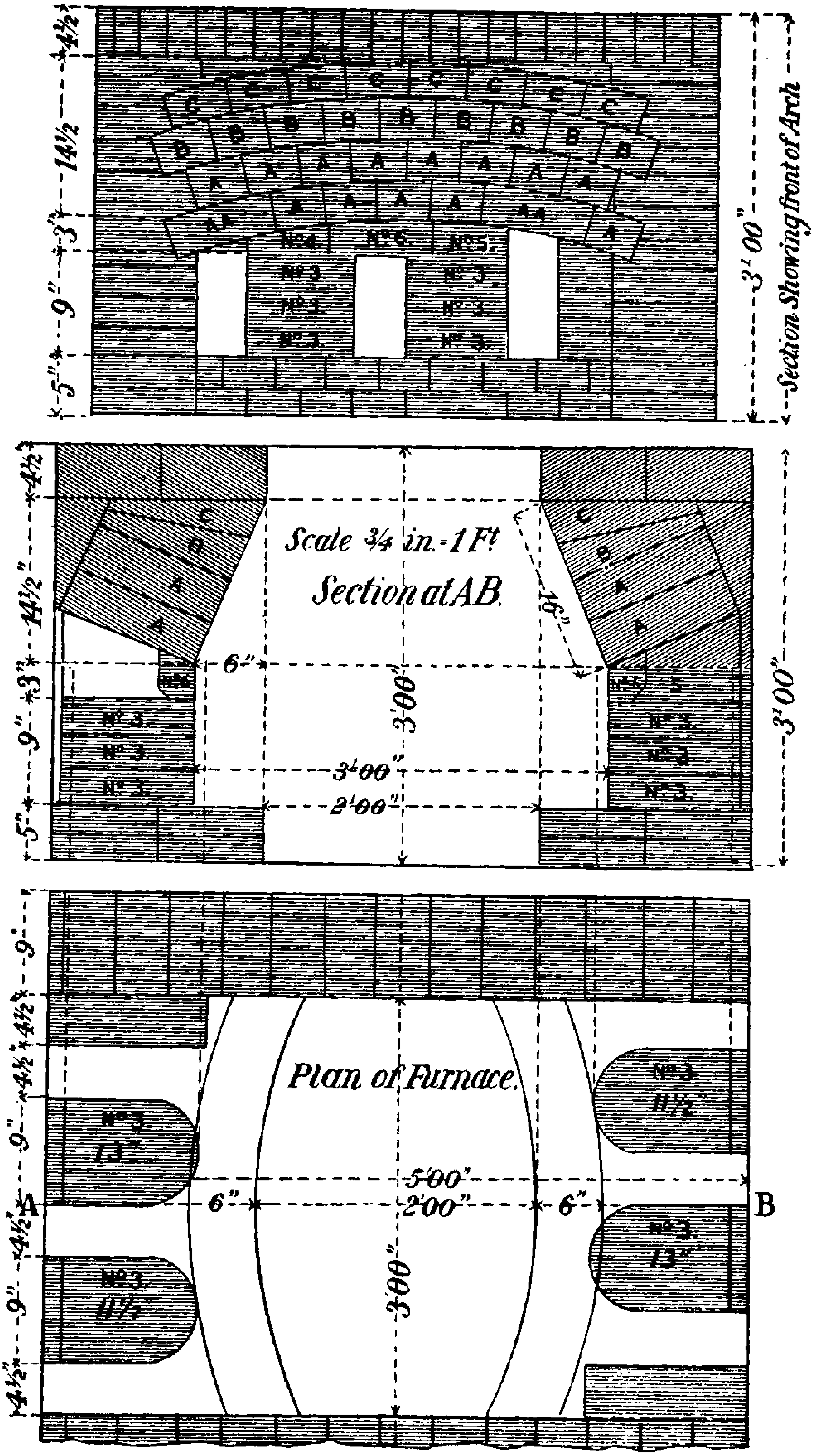
on account of the sudden expansion of its free silica at high heat. Cracks may then open in the brick wide enough to let even carbon lumps of hazel nut size drop into them from the descending burden; and when, at a receding temperature, these cracks become partly closed, then the carbon lumps that have dropped in will be held so tightly as to give rise to the supposition that the brick had been ruptured by their expansion. This belief is apt to be strengthened when other (but smaller) aggregations of carbon are found to obtain in *unfractured* parts of the same brick, into which they could not have dropped from without.

The conditions for the complete desulpurization of contained pyrites obtain sometimes in the fire-brick kiln, but not in the blast-furnace lining; and the blast-furnace brick may contain impregnated carbon that has been *formed* within, as well as carbon that has *dropped* in, but neither is likely to cause the rupture of the brick.

Fire-Brick. Special Shapes.—A large proportion of the work done by the leading fire-brick manufacturers is on special orders for all kinds of irregular and difficult work. To endeavor to fully illustrate this department of fire-brick manufacture would be impracticable as well as useless. In order, however, that the reader may have a good idea of the leading specialties in the different departments, ordinarily kept in stock, we have drawn on the catalogue of the well known firm of Harbison & Walker Co., of Pittsburgh, Pa., for the illustrations shown in Figs. 102 to 125. It is of great importance in ordering refractory materials of any character to state explicitly the nature of the service required of the ware, when the orders are given, so that the manufacturer can fill them with the stock best suited for the purpose.

Sorting Fire-Brick—There are three grades of fire-brick which can be recognized. The first or No. 1 is the best and most refractory, and is intended for the severest use, such as the hearth and boshes of the blast-furnace, the exposed parts of puddling-furnaces and steel-mill plants. Its application en-

FIG. 102.



PLAN OF SIEMENS STEEL FURNACE.

forces the use of a very large proportion of calcined and flint clays with the least possible plastic clay which will bind them together. In several places the mixture is composed of about half and half of each of these, with no plastic, and the mixture is ground very severely in a heavy wet-mill for a long time. The more usual charge for a No. 1 brick consists of about 45 per cent. of both flint and calcine and 10 per cent. plastic.

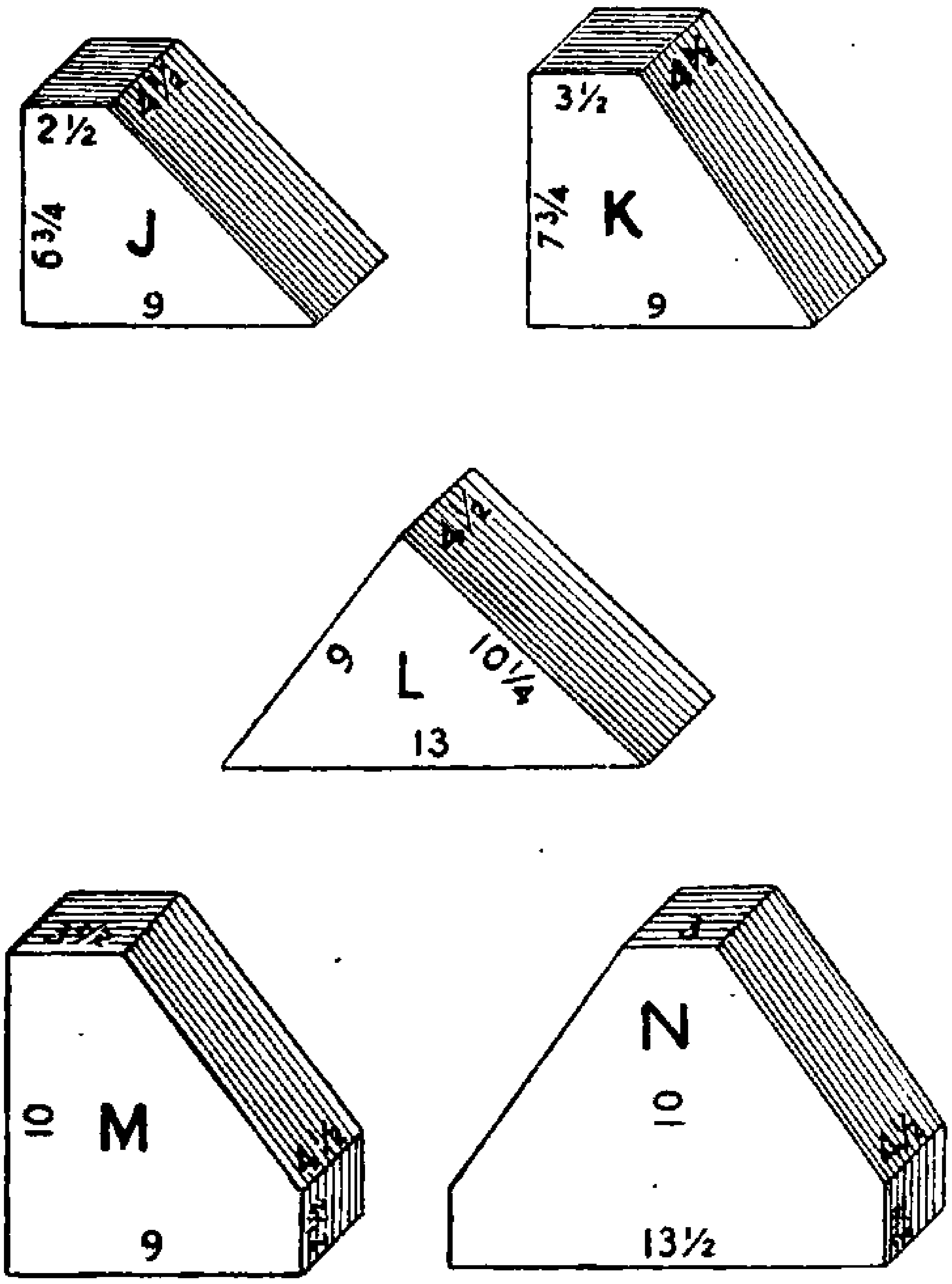
The cohesion among the particles of such a mixture is very slight, and very light friction suffices to shell the brick up into its component parts; it is of course unfitted for use in any position where friction will be brought to bear, but at the intense heat at which they are used, the softening of the clay makes them as cohesive as need be, and in that state the friction of matter as highly heated as the brick has but little effect.

The next well-marked grade of brick has neither name nor number among its makers. It is composed of about equal amounts of both flint and calcine, and about three times as much plastic as the No. 1 brick.

Its proper uses are the same general kind as those for the No. 1 brick, but the product is a little inferior to it. The next grade, or No. 2 brick, is made of about 50 per cent. of plastic, 20 per cent. calcine and 30 per cent. flinty clay; it has a homogeneous appearance on its fracture, is close-grained, and emits a sharp ring when struck with another brick. Such a brick will sometimes stand a very fair heat with no symptoms of fusing, but as a rule it is not fitted for any responsible position. It is excellent material from which to make kilns, etc., except the hottest parts. What might be denominated a No. 3 brick consists of a mixture of several plastic clays, or else a body made of one plastic grade. They are generally vitrified slightly in the burning heat of a kiln, and precaution must be taken to keep them from sticking together. They are excellent for making flues, pavements, boiler-settings, chimneys, etc., and as they can be well made by a machine they ought to be furnished at low rates. The burning of these various grades of brick demands considerable technical skill. The products ex-

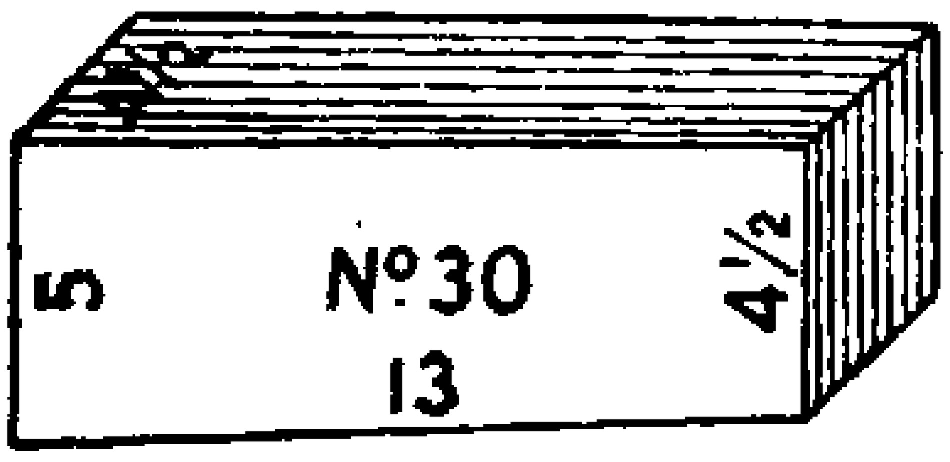
hibit many phenomena which are very interesting; iron, in particular, is noticed in the black blotches which its union with silica has caused.

FIG. 103.

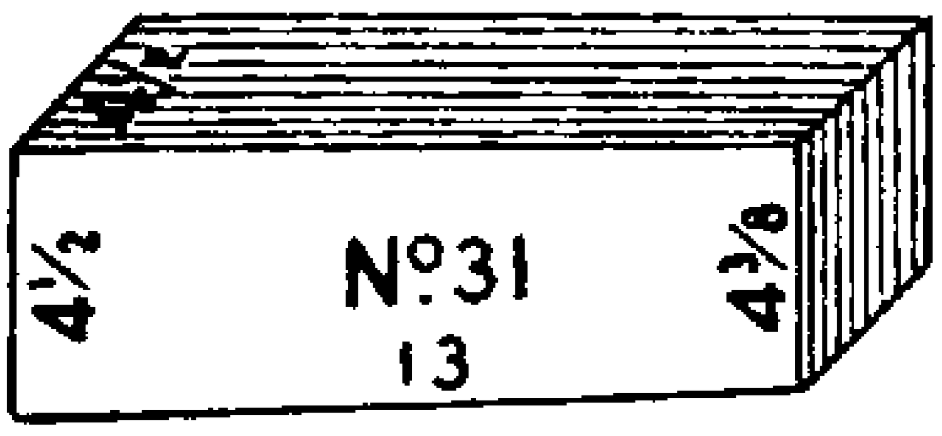


SIEMENS REGENERATOR BLOCKS.

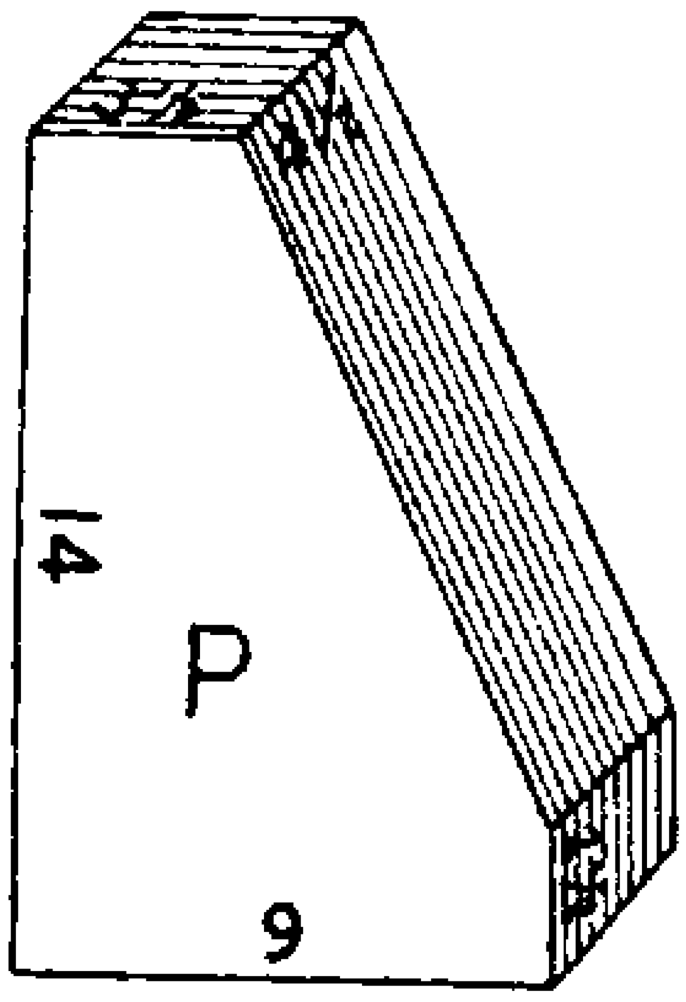
FIG. 104.



WEDGE FOR FURNACE ROOF.



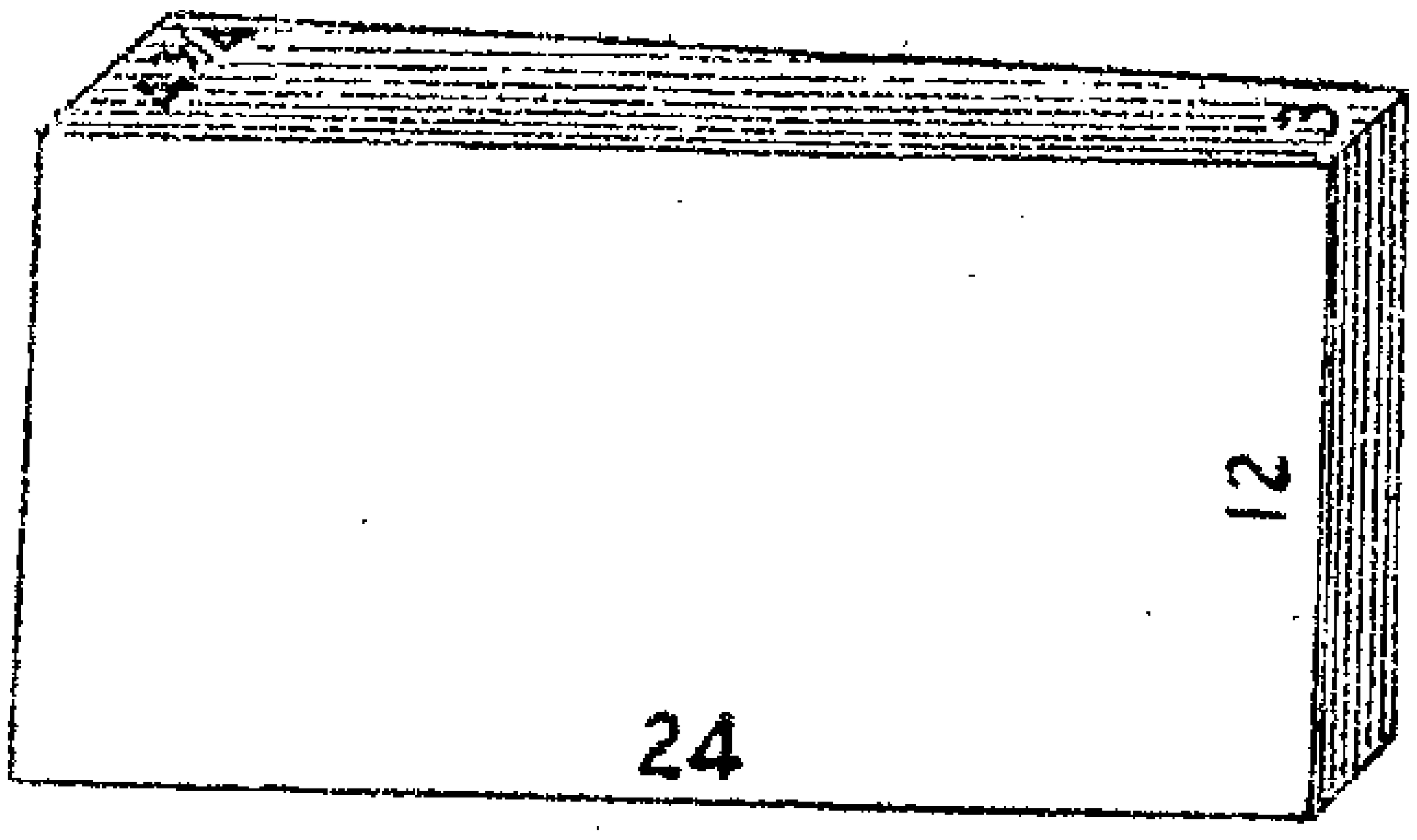
WEDGE FOR FURNACE ROOF.



SKEW FOR FURNACE ROOF.

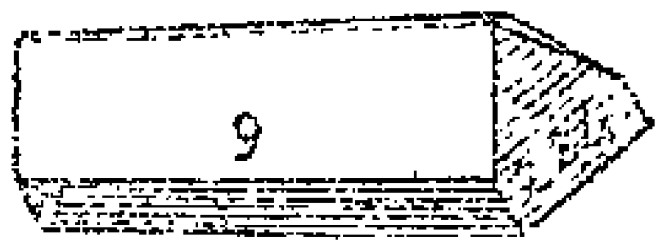
SIEMENS HEATING FURNACE BLOCKS.

FIG. 105.



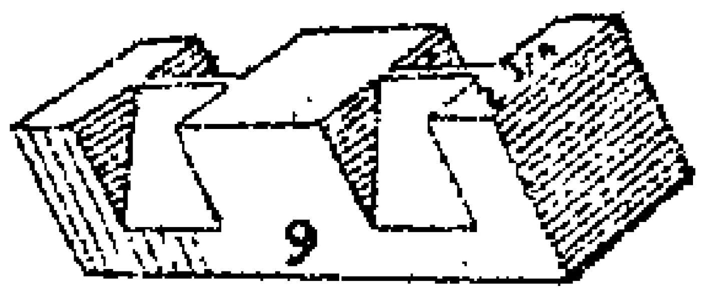
ARCH TILE FOR DOOR OF FURNACE.

FIG. 106.



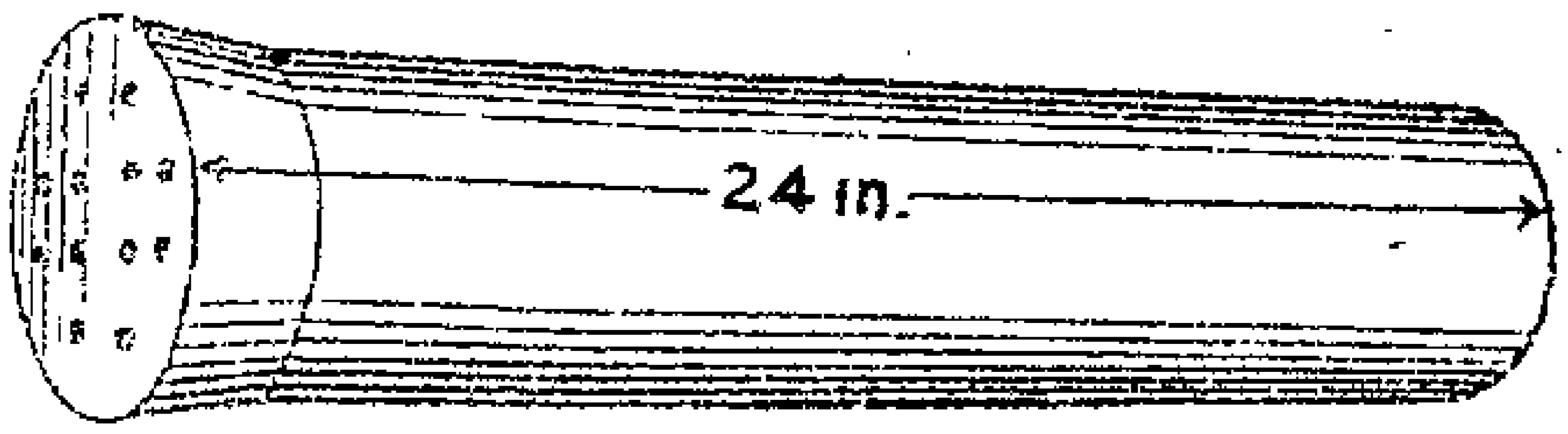
SWINDELL'S PATENT CHECKER.

FIG. 107.



MCKENNA'S PATENT CHECKER.

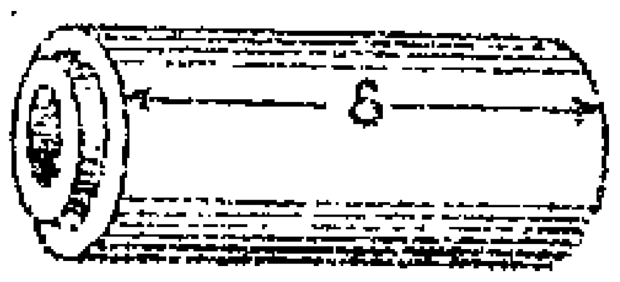
FIG. 108.



BESSEMER CONVERTER TUYERE.

The following sizes of tuyeres are made:
Length of tuyere, "21 inch," "22½ inch," "24 inch."
Diameter of tuyere, 7 inch large and 5¾ inch at shoulder, 5½ inch small end.
Size of hole, ⅜ to ½ inch each.
Number of holes, 7 to 12 in each tuyere.

FIG. 109.



8 INCH SLEEVE, FOR STOPPER ROD.

FIG. 110.

4 INCH SLEEVE, FOR STOPPER ROD.

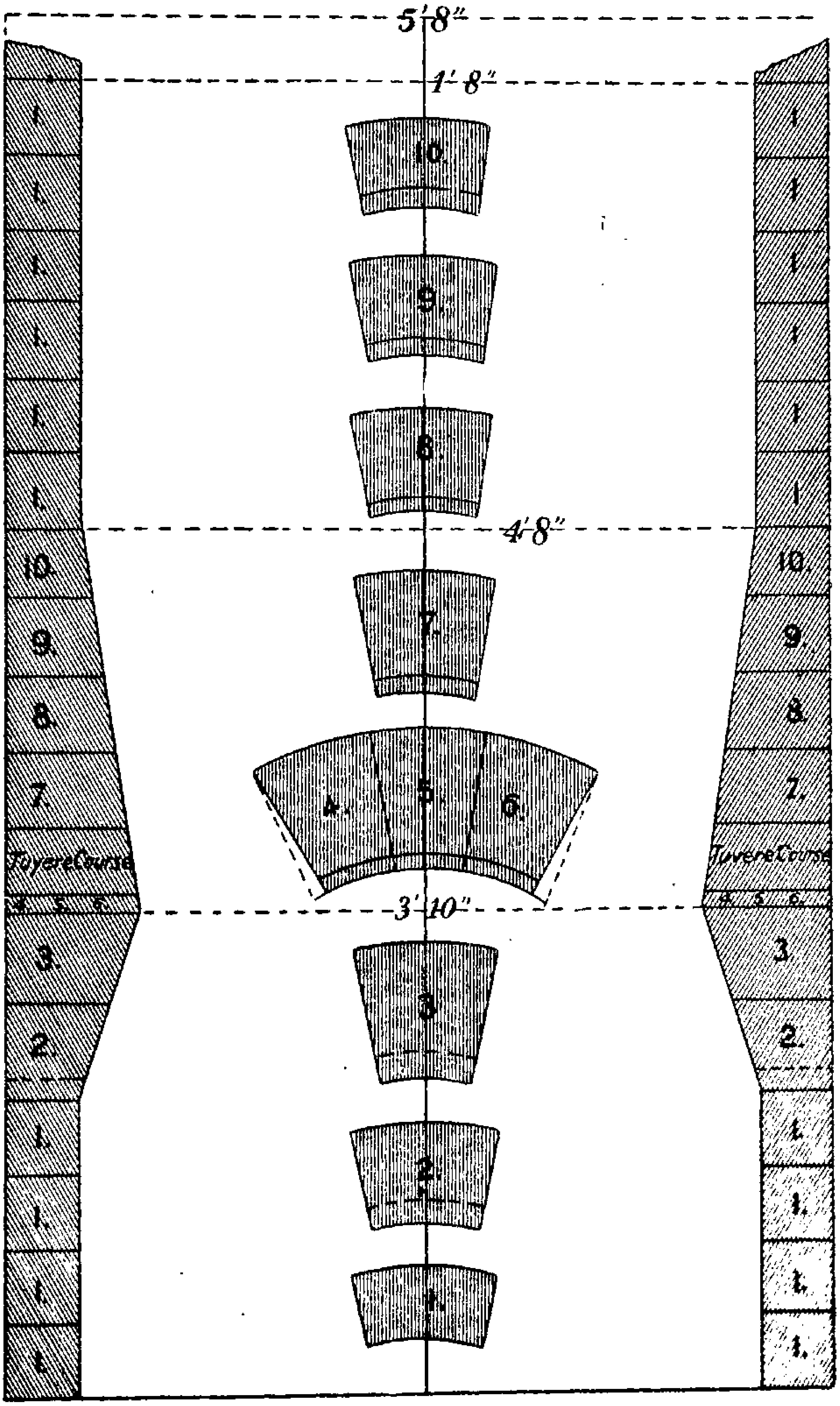
FIG. 111.

4 INCH LADLE NOZZLE.

The following sizes of laddle nozzles are made:
4 inches long, with 1¼ inch hole for bottom casting.
4 inches long, with 1½ inch hole for bottom casting.
4 inches long, with 1¾ inch hole for bottom casting.
4 inches long, with 1⅞ inch hole for bottom casting.
4 inches long, with 2¼ inch hole for top casting.

Often a nail, bolt, or some stray piece of iron gets into a kiln of brick. Its effects can be seen in a large conical hole in the brick, lined with the black cinder of iron, and extending down-

FIG. 112.

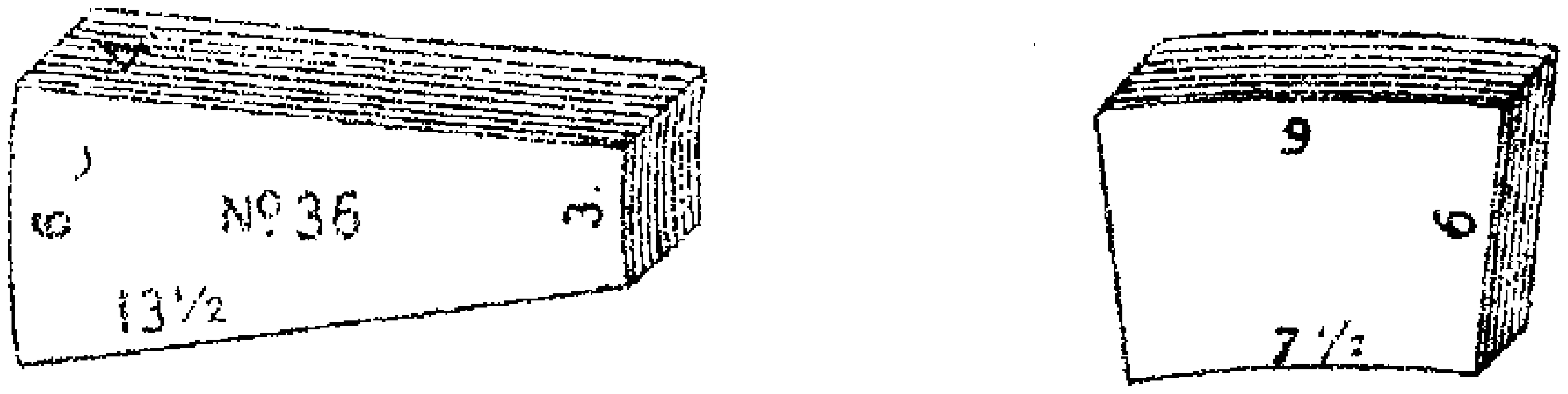


SECTION OF IRON CUPOLA.

ward as far as the iron lasted. The blackening of the faces of the arch brick and those most exposed to the direct heat of the fires has often been mentioned by brick men as being the result of impure fuel and sulphur in the coal. This explanation is incorrect; sulphur, *i. e.*, sulphide of iron, when burned in a grate would decompose to SO_2 or sulphurous anhydride, and in that state would pass into the kiln. The only effect the gas could possibly have on hot silicate of alumina or any body likely to be present in clay, would be to recombine in the same state from which it has just been expelled by a less heat than is met in the inside of a kiln. The true explanation is this: the heat on the brick that are blackened is more intense than on any other part of the kiln, and they are rendered softer and nearer to fusion; while in this pliable state the draft from the fires just outside carries in a very appreciable amount of dust and ashes, which lodge on these portions and flux outside to the black crust seen.

Blocks, Tiles and Special Pieces, and their Manufacture.—In addition to the manufacture of fire-brick the same establishment usually produces many other kinds of wares, notably, blast-furnace linings and special pieces.

FIG. 113.



SPIEGEL CUPOLA BRICK. SIX INCH CUPOLA BRICK.

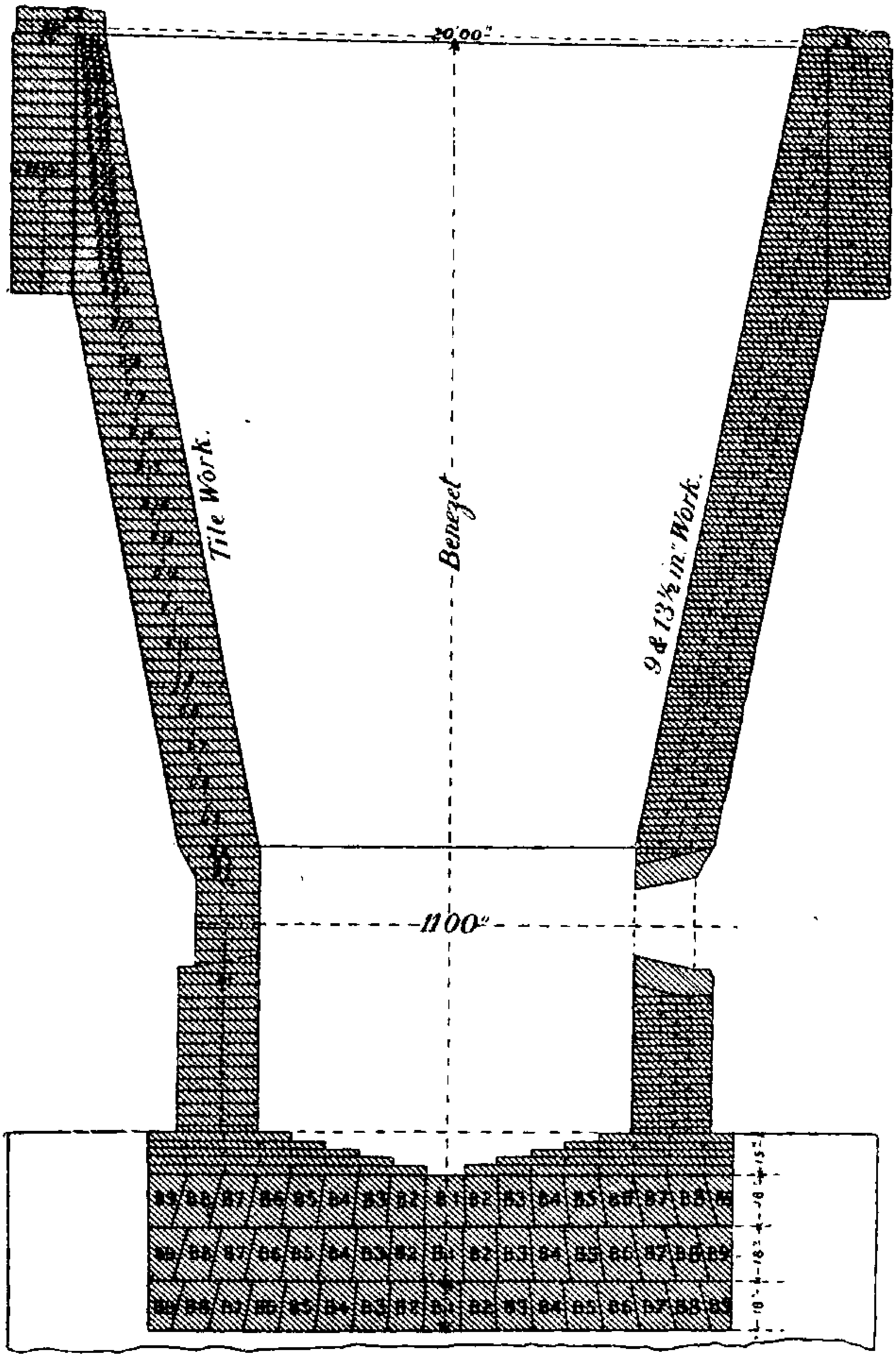
All sizes made to order.
For sizes kept in stock.

CUPOLA LINING BRICK.

The severe service to which the linings of blast-furnaces are now subjected, makes it essential in a good lining not only to be hard friction, but "highly refractory" as well. Years ago any brick that met the first condition was acceptable; but with the practice of the present day—close-top furnaces, improved

hot blasts, high pressure, etc.—it has become of the greatest importance that the brick used should be highly refractory.

FIG. 114.

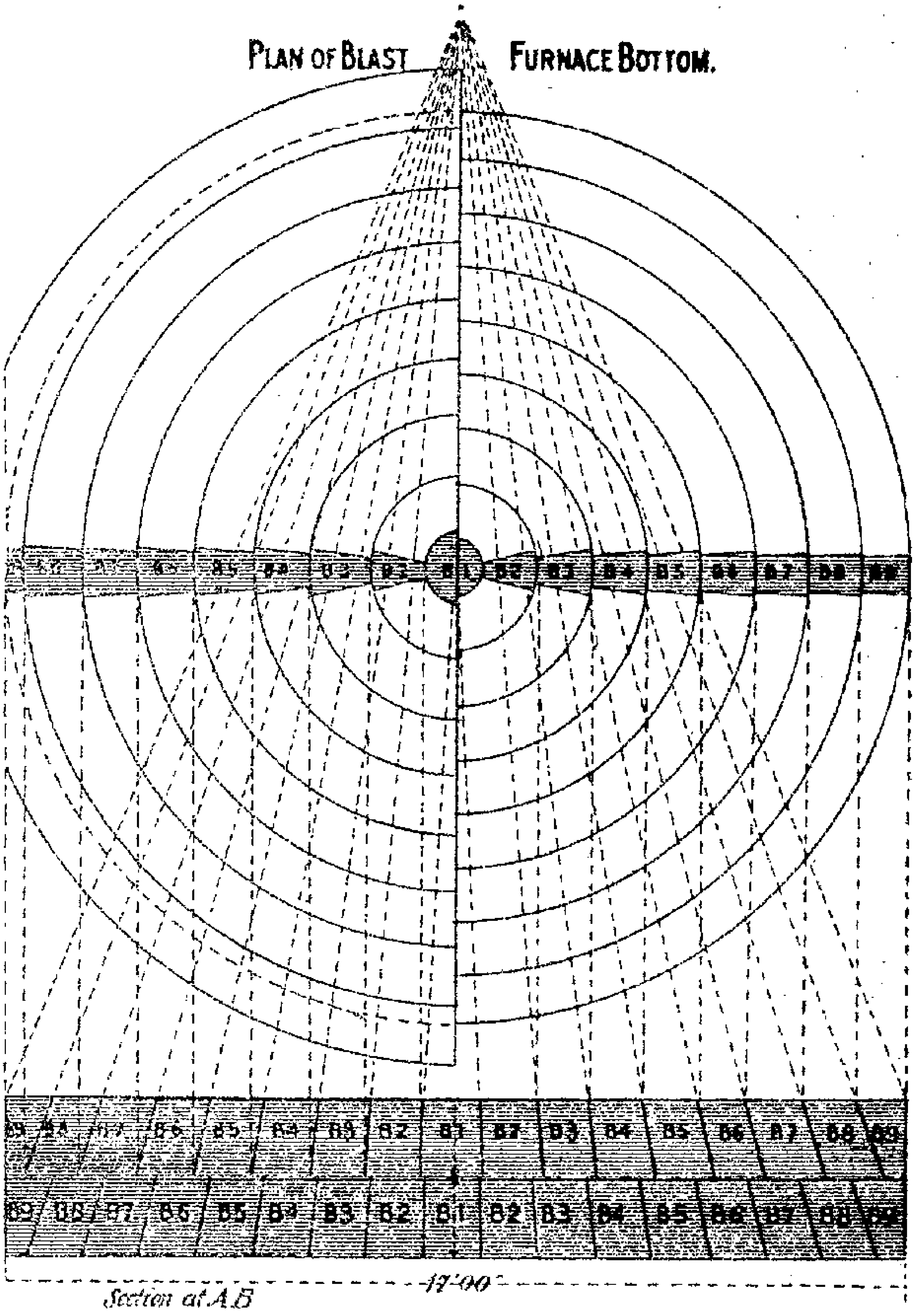


BLAST FURNACE CRUCIBLE AND BOSH.

The above illustration shows a section of a modern 20 foot furnace. The lining on one side is shown as built with 9 and 13½ inch brick, the other as formed with blocks four inches thick, and in length corresponding with the thickness of the wall. The 9 and 13½ inch brick the manufacturers aim always to have in stock; the blocks are only made to order.

To make a lining possessing these qualities requires not only that the stock used be of the best quality, but that the mechani-

FIG. 115.



BLAST FURNACE BOTTOM BLOCKS.

The engraving as shown in Fig. 115 will give an accurate idea of the construction of The Harbison & Walker Co. furnace bottom. The lines forming each of the four sides of each block are radials from a given center, making a perfect key out of each, and thus effectually preventing all danger from "floating."

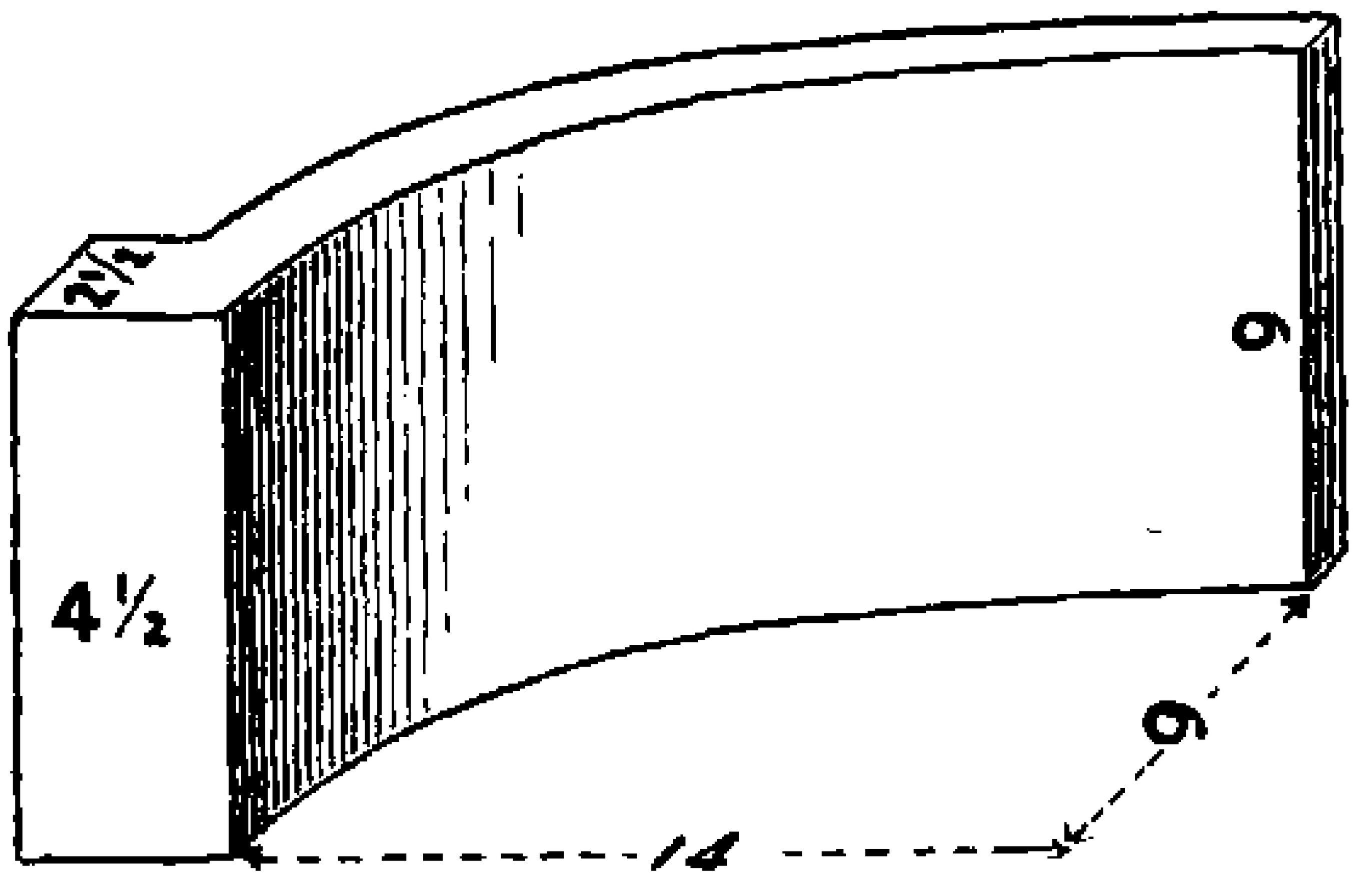
It will be noted how completely the upper course breaks the joints of the course underneath, the same blocks being used in each.

Three courses of these blocks are used in most of the large furnaces, and in others from one to two.

cal structure of the clay be such as to permit its being worked into a compact body. With these given, however, there may be an entire failure in making a hard-friction brick, so much is there depending upon the proper manipulation of the clays and the burning of the brick.

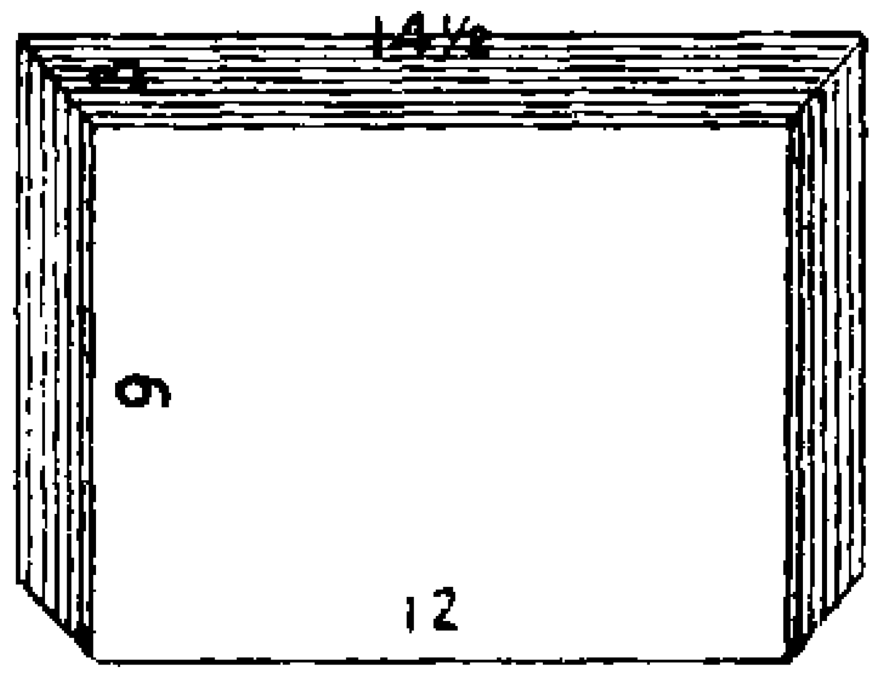
The nature of the service required of the brick in the different parts of the furnace differs so widely, that no single brand of brick can be made to answer all purposes.

FIG. 116.



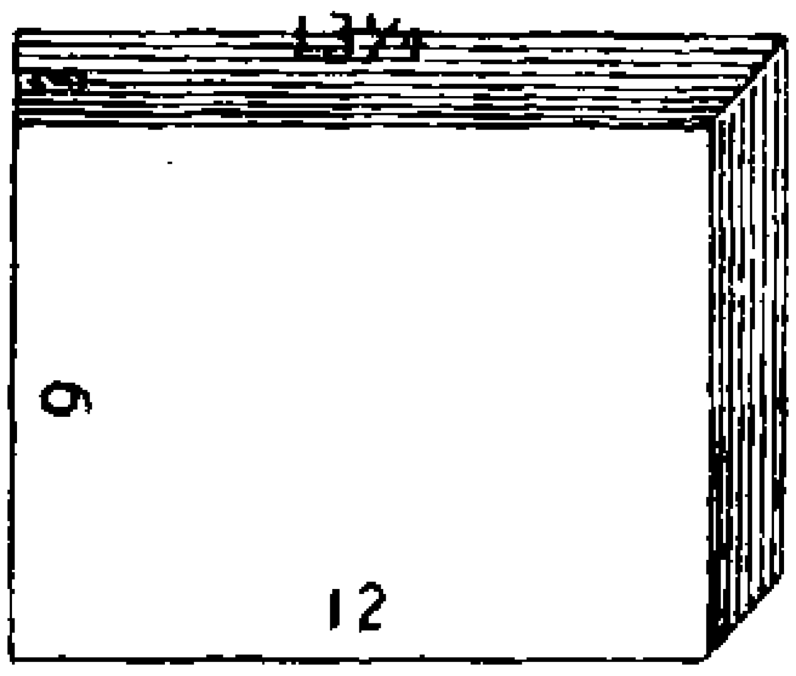
14 INCH AFT BOILER TILE.

Sizes kept on hand:
12 inch aft.
13 inch aft.
10 inch aft.



12 INCH CENTER BOILER TILE.

8 inch center. 11 inch center.
9 inch center. 12 inch center.
10 inch center. 13 inch center.
14 inch center.



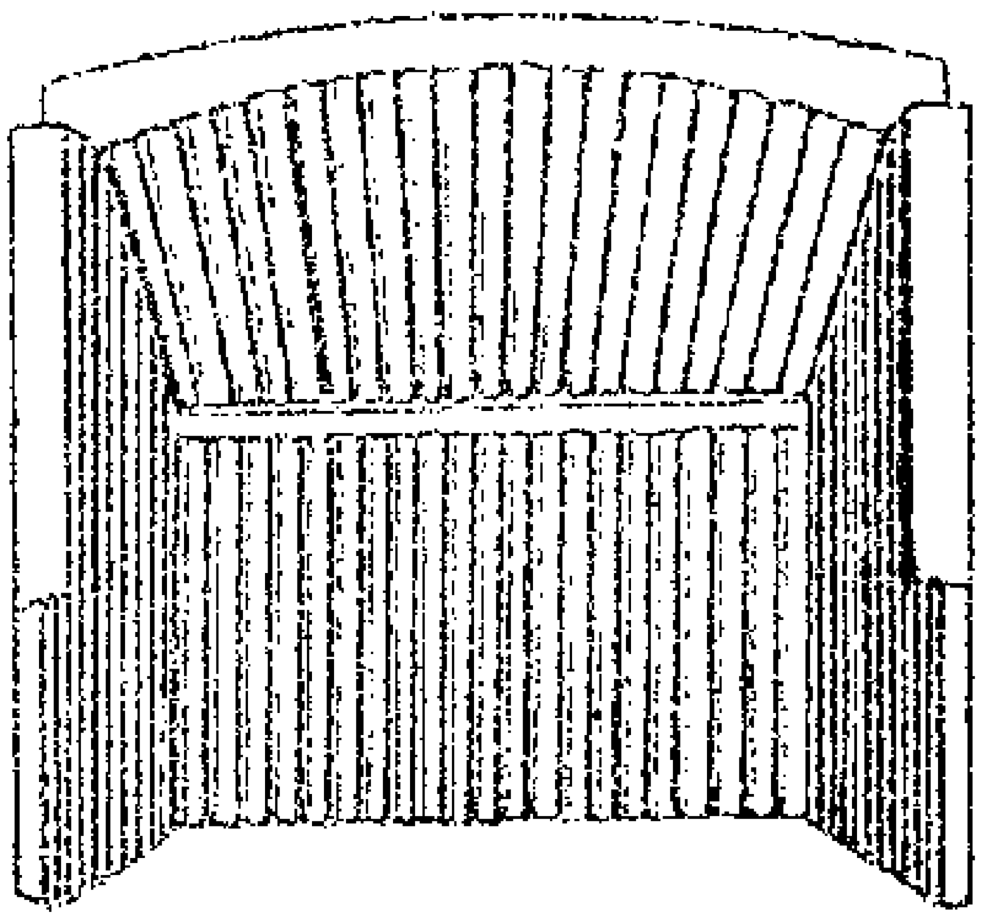
BOILER TILE.

12 INCH SIDE BOILER TILE.
Sizes kept on hand:
10 inch side. 14 inch side.
12 inch side. 16 inch side.

In speaking of this subject The Harbison & Walker Co., of Pittsburgh, Pa., say:

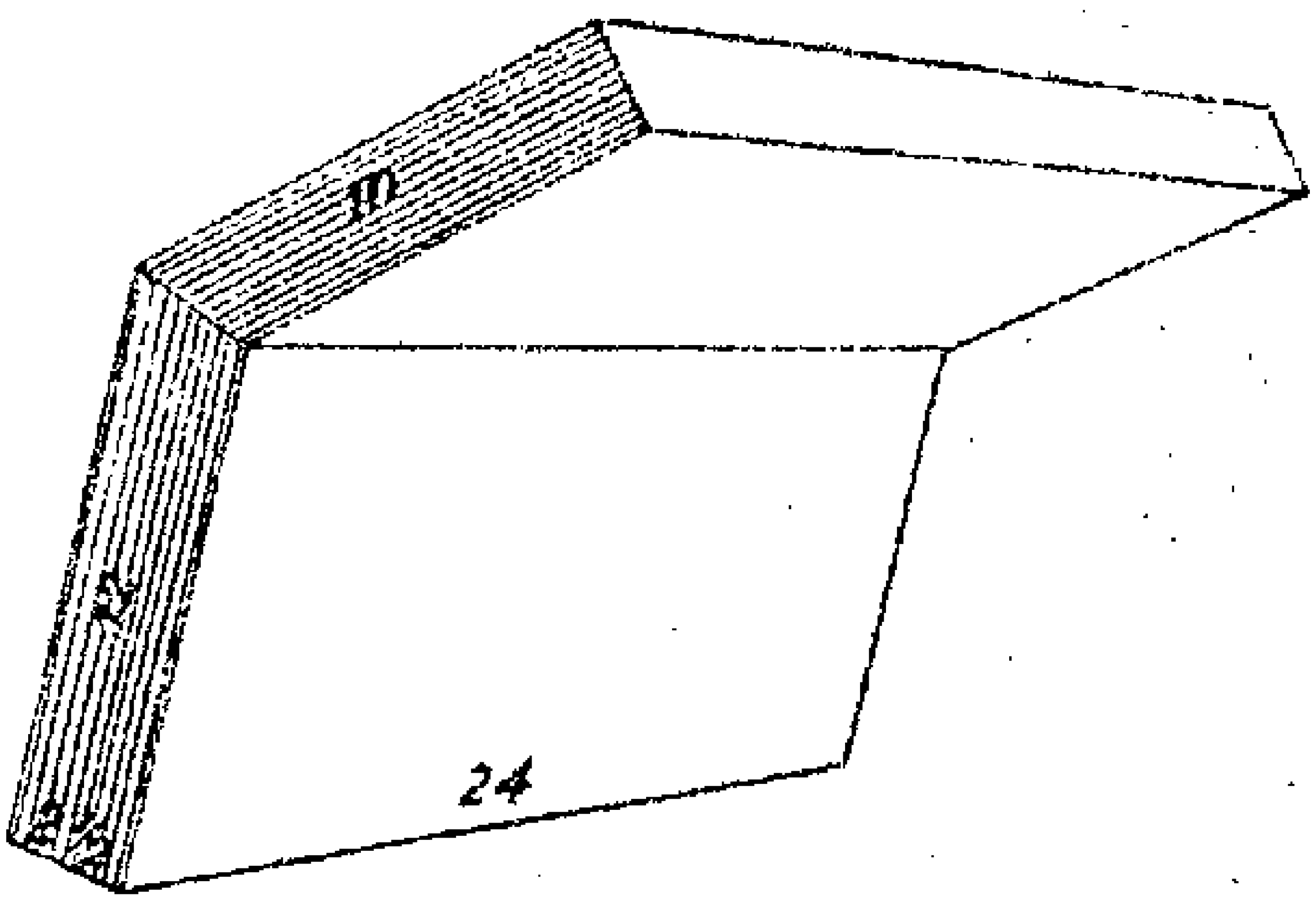
"Our practice for many years has been to make three grades of brick, each adapted to a particular part of the furnace. 'Benezet' is always used in the bottom, hearth, and bosh; 'Clarion' in the lining above the bosh, and 'No. 2 Star' in the

Fig. 117.



STOVE LINING.

Fig. 118.

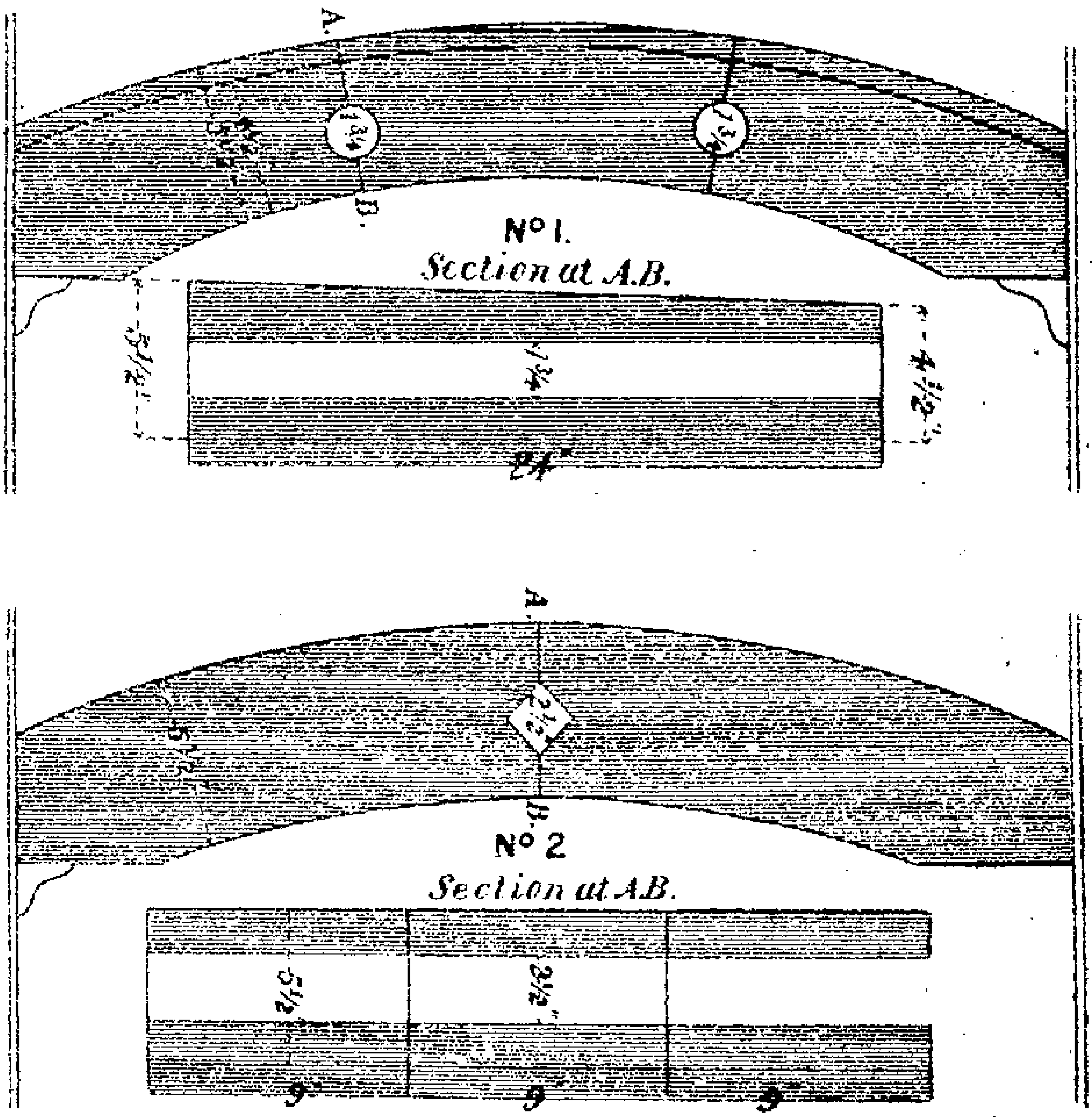


SET OF 24 INCH GRATE BACKS.

Sizes kept on hand:

18 x 10 x 2½	22 x 12 x 2½
18 x 12 x 2½	24 x 10 x 2½
20 x 10 x 3½	24 x 12 x 2½
20 x 12 x 2½	26 x 10 x 2½
22 x 10 x 2½	26 x 12 x 2½

Fig. 119.

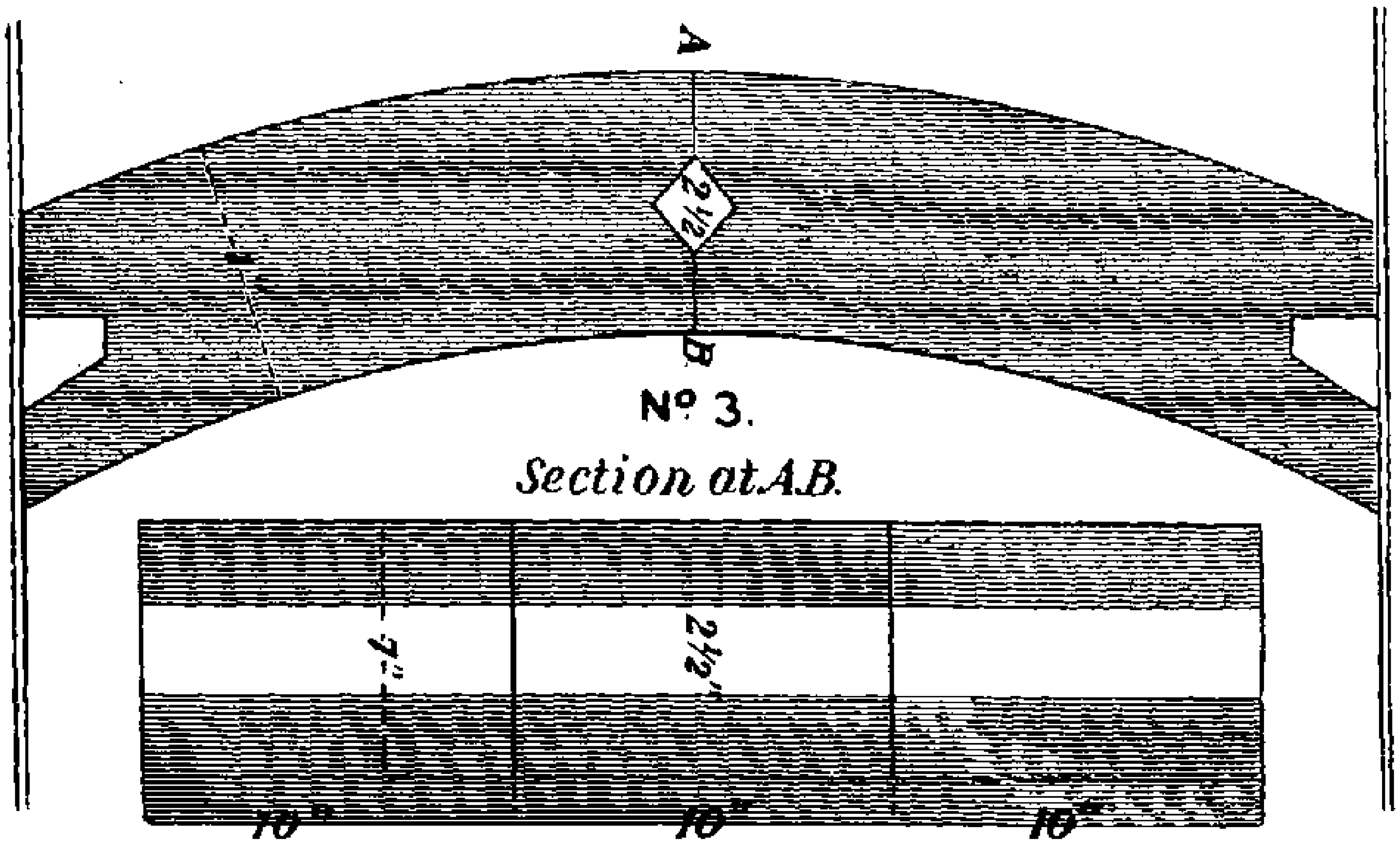


top. All the brick are plainly branded to avoid any interchange of stock.

"We are confident that the best results will be secured by using the block or tile-lining above the bosh. Such is nearly the uniform practice at the present time. In the hearth and bosh 9 and 13½-inch brick are generally used. For the hearth and lower part of the bosh, these answer every purpose; but for the upper part of the bosh, we think the blocks will do better.

"To meet emergiencies a large number of these brick are carried in stock of each of the three grades of stock necessary in a lining: 'Benezet,' 'Clarion,' and 'No. 2 Star.' Block or tile

FIG. 119 (*Continued*).



RAILROAD SPECIALTIES (CONTINUED).

The illustration, Fig. 119, shows the more common varieties of locomotive blocks for fire-box arches. In No. 1 the arch is formed by three blocks running from front to back, and keyed together on the sides of the block.

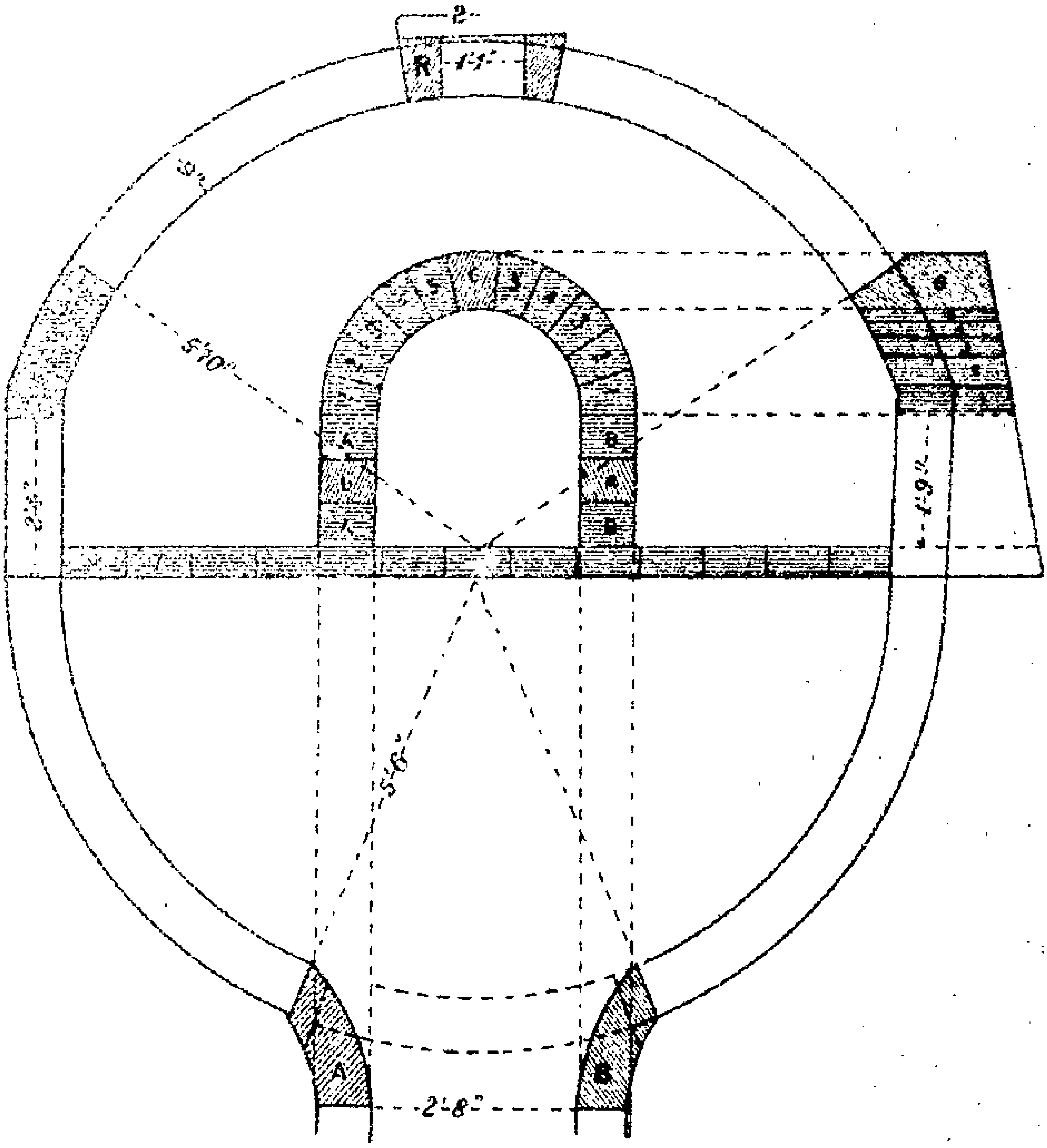
No. 2 is formed with six blocks, three on each side, meeting over the center of the box, and secured by a square key.

No. 3 is also formed with six blocks, put together in the same way as No. 2: but instead of being supported by brackets on the side of the fire-box, as in No. 1 and No. 2, these have recesses formed in the ends of the blocks to receive the bracket.

linings, however, are only made to order, as it is necessary to adapt the form of the blocks to each particular furnace. It is important, therefore, that those using such a lining should anticipate their wants by ordering two to four months in advance."

The manufacture of blocks and tiles requires great care, particular caution being exercised to see that the mixtures of the clays and calcine are in correct proportions. To agree with the shrinkage allowed for in the molds as being exact and uni-

FIG. 120.



COKE OVEN WORK.

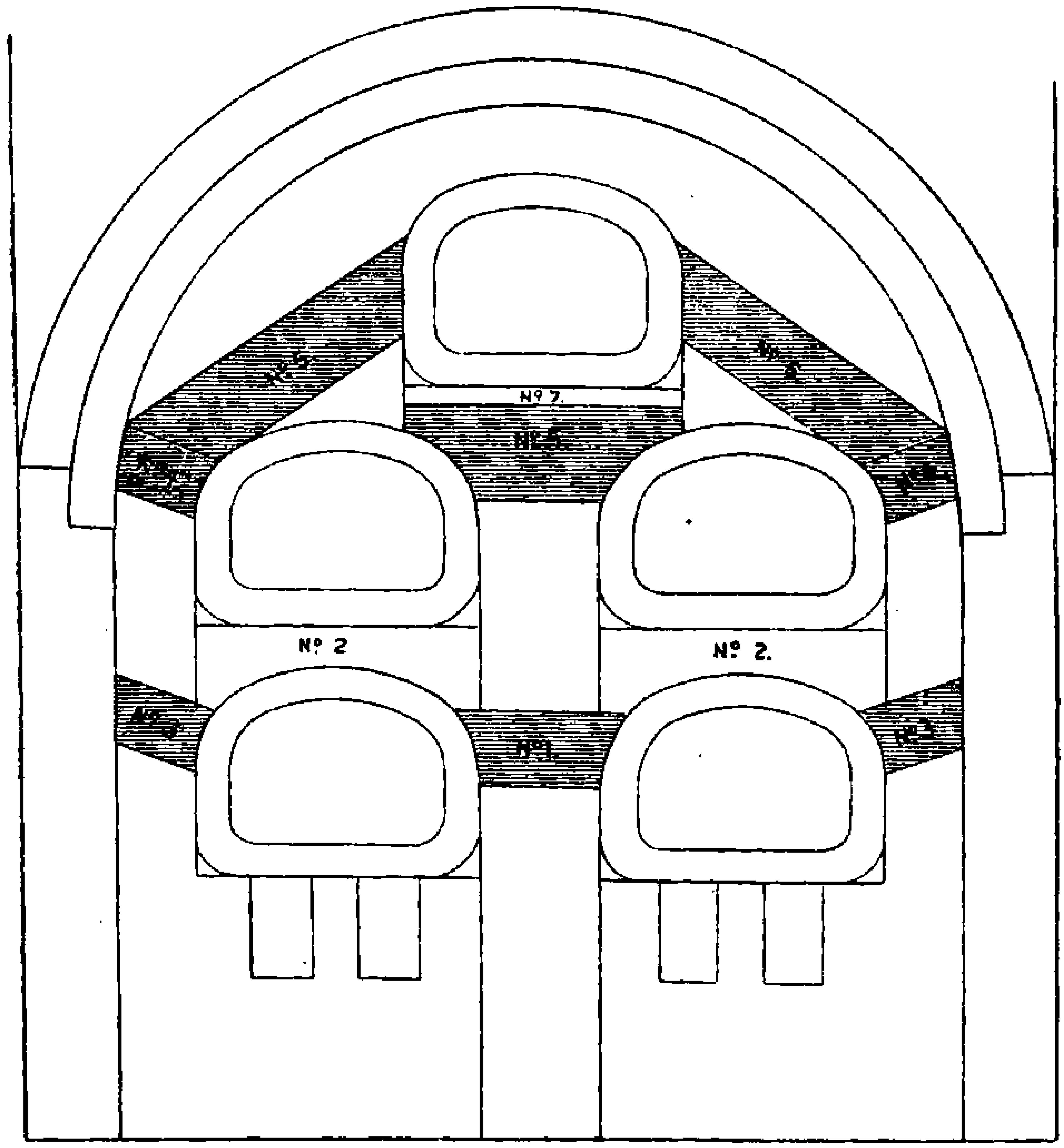
The above, Fig. 120, represents The Harbison, Walker Co.'s coke oven work; the upper half of drawing representing a section through the middle of oven, the lower part being one-half of the ground plan showing the front opening. The 9-inch brick used in this work are shown in the cuts on another page, and all the shapes used are indicated in the drawing, as follows:

R—Ring, or Oven Vent.	S—Skew Back.	R W—Ring Wall Brick.
A—Small Jamb.	1 to 6—Door Arch.	T—Bottom Tile (10 x 10 x 4).
B—Large Jamb.	C—Crown Brick.	

form to size ordered, it is important to have this, as it is necessary that the clay should be ground regularly as to stiffness; great care is also required in dressing the tiles when suf-

ficiently hard to handle, seeing that not only the tiles are smooth and level on the face and sides, but also that the edges are sharp; the tile, when finished, being equal in appearance to a wood block the same size and shape.

FIG. 121.



GAS WORKS.

The above drawing shows the tiles and blocks necessary in setting a bench of fire clay retorts, as follows:

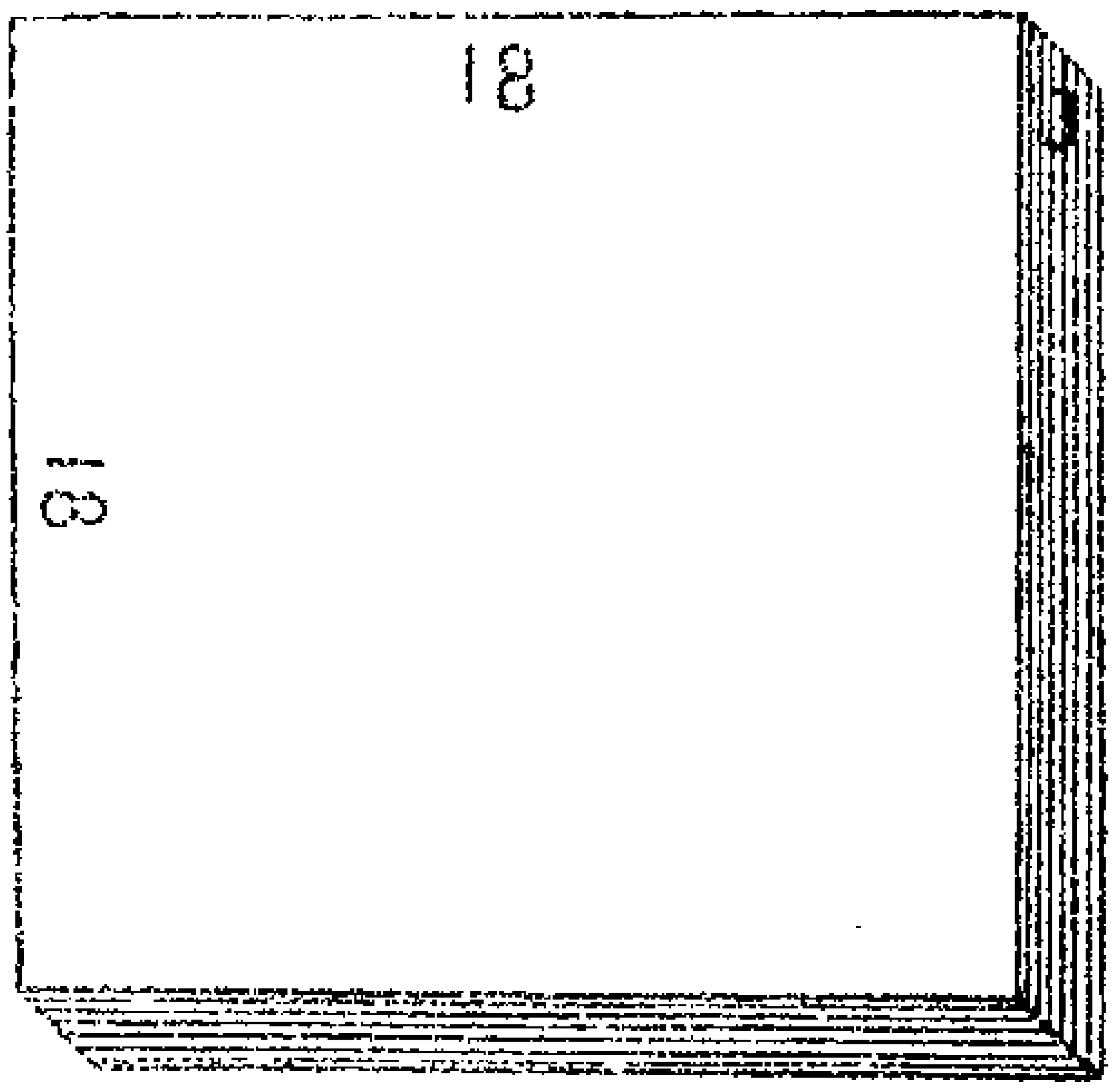
6 pieces of No. 1, 5 inches thick.	6 pieces of No. 5, 5 inches thick.
12 pieces of No. 2, 5 inches thick.	12 pieces of No. 6, 5 inches thick.
12 pieces of No. 3, 5 inches thick.	6 tiles, 14 x 14 x 2 inches, No. 7.
12 pieces of No. 4, 5 inches thick.	6 tiles, 12 x 14 x 2 inches, No. 7.

18 feet of corner pieces for each retort, No. 8.

One defect in making large tiles or blocks—that is, those containing more clay than the moulder can handle and put in the mould at one time—is that in preparing it on the table it is

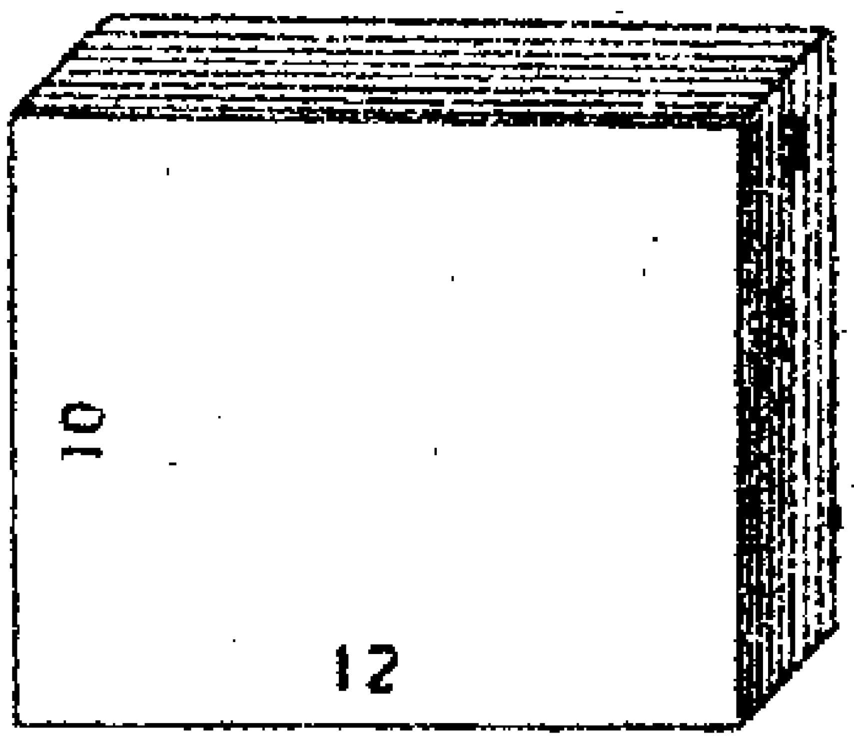
rolled in sand. Two or more separate balls of clay coming together in the same mould are liable to make and leave what are termed sand-cracks, the sand preventing the clay from being properly united together in the mould; the tile or block in such case coming out of the kiln cracked or broken, and in

FIG. 122.



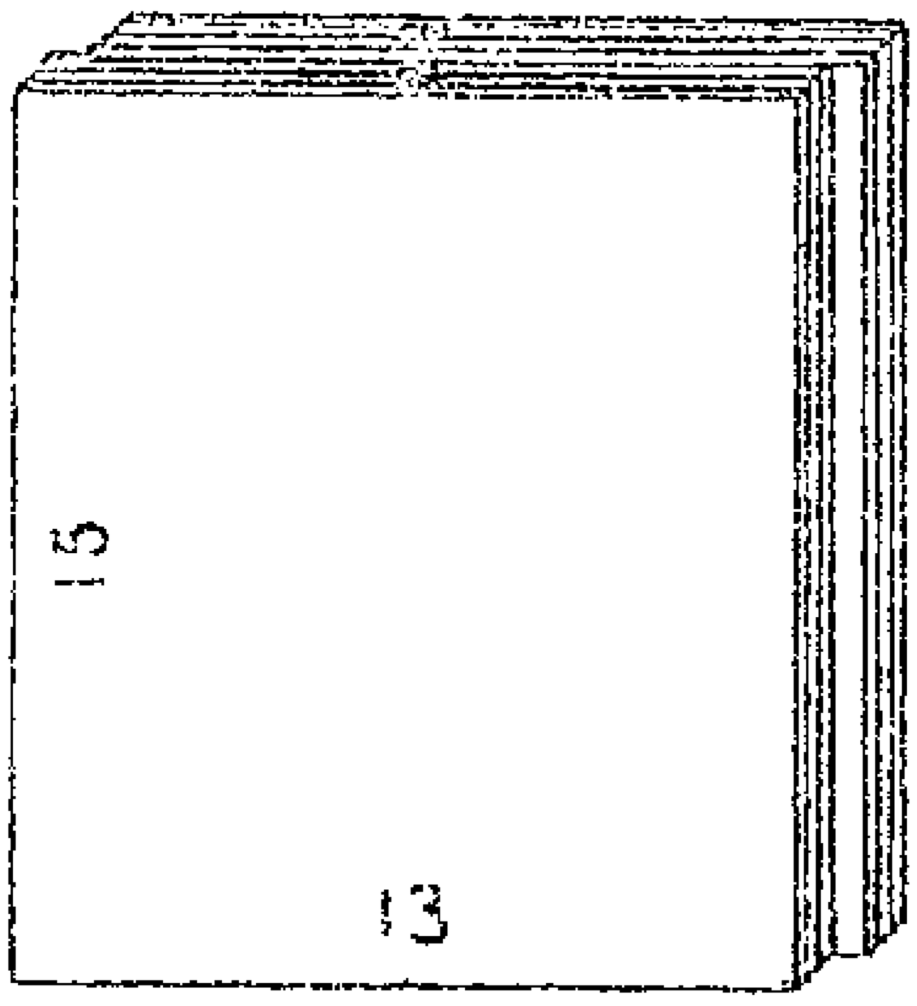
COVER TILE. FOR STEEL COKE HOLDERS.

FIG. 123.



FLOOR TILE.

FIG. 124.

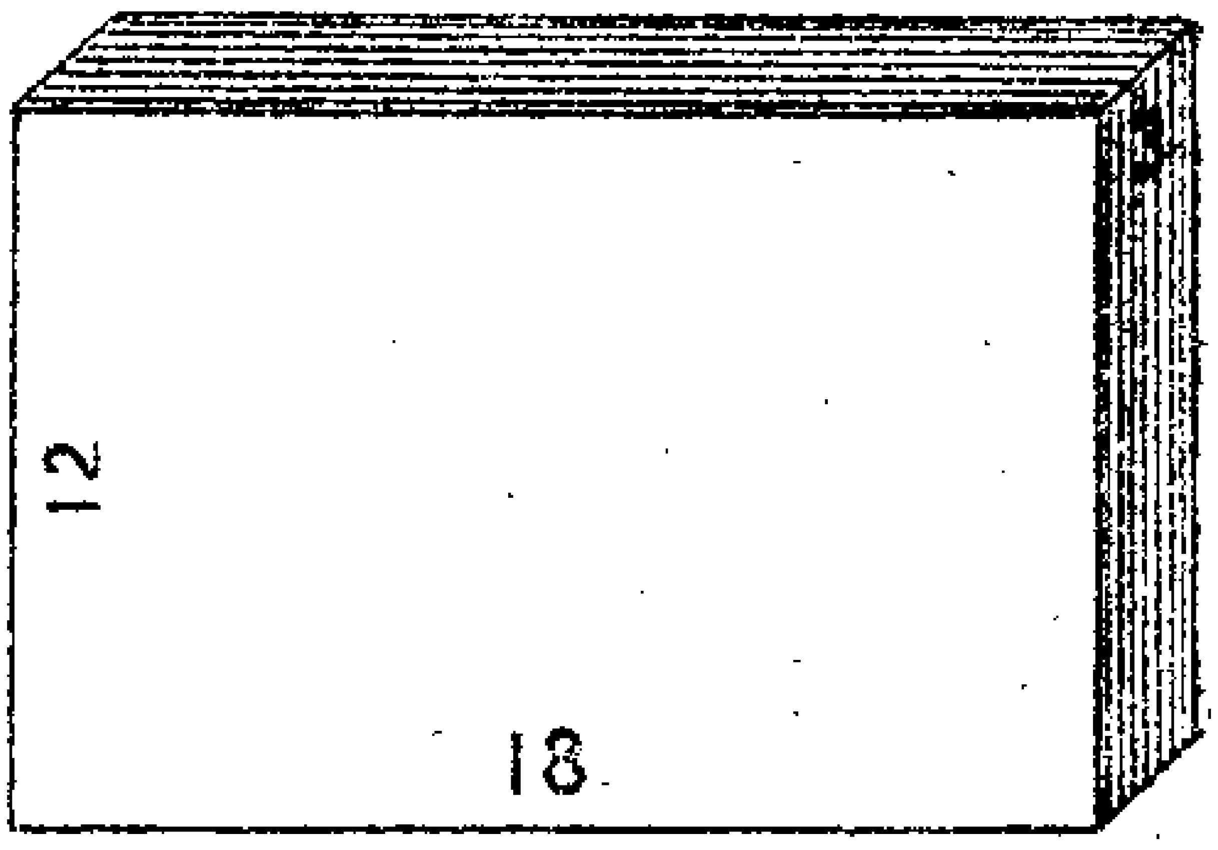


RABBETED TILE FOR GREENHOUSES, FLUES, ETC.

Sizes kept on hand:

13 x 13 x 2½. 13 x 15 x 2½.

FIG. 125.



SLABS AND STEAMBOAT BRIDGE WALL TILE.

Sizes kept on hand:

18 x 12 x 2. 24 x 12 x 3.
18 x 12 x 3. 18 x 14 x 3.
24 x 14 x 3.

place of being salable goes back to the mill. A machine for making tiles and blocks is now in use, which not only does away with these sand-cracks, but also makes more solid and better work at less cost. This machine is in all respects the same as the smaller size sewer-pipe press, only that in place of

the die a box is bolted to the bottom with a flat plate around the outside of the bottom of the box. Below this is another iron plate or table underneath, and in the center of which it is connected with a screw secured to framing in the floor; on the screw are four cross-handles for working the same. The mould, after being sanded, is placed on the bottom plate, the screw given a turn, tightening the mould up to the top plate, the lever is pulled as in making sewer-pipe, forcing the clay into the mould, the pressure being sufficient to force the clay past the box and under the bottom of the top plate to the sides and ends of the mould; the steam being then cut off by the lever, the screw is again given a turn, liberating the mould from the upper plate sufficiently to allow the cut-off wire to be drawn between the top of the mould and the underside of the plate. The mould is then drawn out on to a block at one side to be struck or planed and another mould run between the plates as before mentioned. In this way of making blocks and tiles every one is perfect and comes out of the kiln perfectly sound. This plan of making fire-clay blocks and tiles is recommended to such of our readers as are large makers, and to manufacturers who have not heretofore cared to make locomotive and similar tiles on account of the great loss arising from the reasons before described.

FIRE-BRICK WORKS AND THEIR CONSTRUCTION.

The arrangement or plan upon which a fire-brick works should be built is of the first importance. Any person conversant with the business will notice in traveling through the different parts of the country and inspecting the various plants, the varied styles adopted, and not unusually the entire absence of arrangement and the many disadvantages under which the proprietors of such works are laboring, and which disadvantages might have been obviated. This is in some degree due to the fact that in the first instance a small plant only was contemplated and built, and not making any provision for extensions. In the erection of a new fire-brick works, the first subject re-

quiring attention is the amount of capital at disposal. This question having been satisfactorily settled, one-third of that amount should be set aside as working capital. In default of this precaution you commence with difficulties, and continue to labor under them until your credit is gone. The works shut down, some other persons come in and buy them at about one-third the cost, and reap the advantages you had anticipated. Our trade papers reveal this fact in almost every issue.

The next point is to get a plan drawn, not just of the works you propose to build, but considerably larger, and particularly as regards dry-floors and kilns; taking also into account stock room for clay and brick for an increased output. You can then build as much of the plant as your capital will permit or circumstances justify, so that as your business is a success and you see your way clear to extend the works, then you can carry out a further portion of your original plan. In following this course, your works are convenient and uniform. You should always in the first instance put down your machinery, including engine power, in excess of your present requirements, to be prepared for this extension. The usual way is to calculate how little horse-power you can manage to do with, and, when you make an extension, engine and boiler will be sold at a sacrifice to make room for a power plant of larger capacity. The difference or loss between the latter and former policy would build a new kiln or dry-floor.

In drawing plans for a new works, in order to secure every convenience and economy in labor, you must arrange your plant so that your material always travels in one direction: that is, from the clay-bank to brick in car or stock-house; thus clay-bank, mill, moulding side of dry floor, pressing side of dry floor, kilns, railroad, stock-house—a straight line would run across each in the order named. The buildings containing the engine and mills should be separate from the moulding-room, but attached to the same on the outside, so that the pug-pans will be in the centre of the outside walls. As it is not the object of this book to advertise any particular machinery to the

detriment of other makers, individual names will not now be mentioned. What we would say is, before you definitely decide as to the type and make, see the machine in operation in successful works, then exercise your own judgment.

As to boilers, on no account buy a second-hand boiler, for, in risk, stoppages and repairs, it would probably be dear to you as a gift. In arranging to put down your boilers, allow room for the addition of one or more, as you find it necessary to extend your plant.

In deciding what amount of engine-power you require, there should be a surplus of at least one-third more than will ever be required. The engine-room should be entirely separate in order to keep out the dust. A great deal of the wear and tear of engines in fire-brick works arises from this oversight. As regards dry-pans, there is an equal difference in opinion as to whether it is best to drive them with under or over-gearing. In overhead gearing on framework of wood and iron, there is invariably considerable oscillation, resulting in loosening bolts and framework, and finally in breakage. Whereas, in under-geared mills the bearings are short, and the strains are less in consequence, the whole being more rigid and firm. The objection to undergeared mills is, that the driving-gear being below ground-level, sufficient room is not left in the bottom for a man to get around to examine and oil the machinery. In nearly every case where under-geared mills are put down the engineer has to crawl or creep under as best he can, and he does this with the bottom covered with black oil, and perhaps some accumulation of water or dampness arising from imperfect drainage. This state of things in connection with under-geared mills is not imagination; it is the invariable rule, and what is the result? The engineer goes under as seldom as possible, and then not to examine, but to reach as far as possible with the oil-can; the toe at the bottom of the shaft gets hot; the machinery stands for it to get cool, and so losses continue repeating.

It is best, where you have the drainage to do it, in putting

down an undergeared dry-pan to get your foundations out sufficiently deep with walls around the same so that the engineer can go down the steps and *walk* all around. He will then not only go down more frequently, but will be able and disposed to examine the same. This little extra expense in depth will be the best-saved money you can make in the building of your works. If you can get the drainage and this extra depth is given, the undergeared dry-pan is by far the best. If you cannot get the necessary drainage and put it down in the way described, then the overhead arrangement is preferable.

From the dry-pan we next come to the elevators and wet-pan. In examining many fire-brick works we see the same primitive way of wheeling the clay from the wet-pan to the tables, which means additional men and the space occupied by the runs on the dry-floor lost. Amongst the improvements of modern fire-brick works may be mentioned the clay belt—a description of which will probably be interesting to those who have not seen it in operation—the moulders' tables being all along and in line with the wall, as also the wet-pan. A belt conveyor runs along the side of pan and tables at a sufficient height above the latter, so as to leave ample room for the delivery of the clay. On each side of the belt are wood sides, in the bottom of which are affixed rollers on which the belt travels. In these wood sides opposite each moulding-table is a gate; that is, a piece of the side is cut out and attached in place again with a pair of hinges, so that it can be opened across the trough just over the belt. The gate being longer than the width of the trough, it will open at an angle of about 45°. The mill man discharges a pan of clay on the belt, the sides keeping it in place—a boy in charge of the belt opens a gate opposite one of the tables: the clay coming into contact with it at the angle before named, slides along it and off the belt on to the table. The boy then closes the gate, closing up the side, and opens the gate opposite the next table to receive the following charge, and so in rotation. Where seen in work, this belt was supplying clay for five tables and a machine.

Another plan of conveying the clay from pan to tables, which is still better, is to empty the pan of clay into a self-dump car, which is then run over a light tram-road over the tables and dumped down the chute at the table where required. One lad in this way will supply clay for 20,000 brick per day. The point in the latter method of conveying the clay is to have the necessary elevation. The way to do this is to take the clay up sufficiently high when it is in the elevators from the dry-pan, so that the clay may be delivered into the bins at a height to allow the wet or pug-pans to be fixed high enough to discharge the clay in the dump-car. It is much easier with this arrangement to discharge the clay down to the tables than wheel it up, and only requires a greater length of elevator-belt and to have the pug pan about four feet above the upper floor. It is in such arrangements as these where the cost of manufacture is reduced. In the construction of the works we next come to the main building or factory where the brick are moulded, pressed and dried; this building will be from sixty to seventy feet wide from side opposite the mills and of required length. The ends should not be permanently closed, but so put together that any extension may be made at one or both ends as might be desired, and so keep the moulding-room in one open compact building. If thus arranged, the whole of the work is under the manager's eye at one time. Where the roof is high and wet-pan elevated as described, it is advisable to economize what space you can in the same by putting down a floor over the the posts supporting the roof, sufficient flooring being put down to make the blocks and tiles. The heat from the floor below will not only dry them, but will do so very regularly. With respect to the covering for the roof, shingles, felting of every kind, sheet-iron and galvanized, corrugated iron, have all been tried, all of which have proved failures except shingles. No roof covering is more severely tried than that over a brick dry-floor; the heat and steam continually rising and hanging under the roof makes all feltings rotten and short, so that they split when the boards to which they are nailed expand or contract by the action of heat

and damp. Sheet iron from the same causes quickly rusts through and leaks. Galvanized iron is but little better, as the coating peels off and it then rusts. For a roof covering to resist the action of heat and steam inside and sun and rain outside, there is nothing equal to shingles, except a clay tile roof, which would be found too expensive. In connection with the moulding-room, we next come to the important part of it, viz.: the dry-floor.

Steam Drying Floors.—There are various systems of drying brick with exhaust steam from the engine or steam direct from the boilers, and several fire-brick works have now in use dry-floors, in which are laid parallel rows of one-inch iron pipe, over which, in some cases, is laid a floor of cement. In some plants, fresh blast-furnace slag with a small addition of lime is ground in the mill, and when laid over the pipes is run over with a roller; the latter plan has been found to be more satisfactory, as, while making a floor equally as smooth and hard as cement, it is not so liable to crack from the effects of the heat.

One difficulty met with in this system of dry-floor is the expansion and contraction of the iron pipes in consequence of their being at one time hot and another cold. Several methods have been adopted to counteract this. The most successful one is to bury the pipes in loose sand before covering them over with the permanent floor, thus allowing the pipes to draw without breaking the floor.

Manufacturers who have adopted this plan of drying speak in very satisfactory terms of the result.

There is another steam dry-floor much more economical in working and far more satisfactory. It is extensively used in England, a description of which will be of interest:

Parallel brick walls four and a half inches thick are built across the dry-floor to receive the metal floor-plates much after the manner of flue walls to receive tiles, except that in order to have a thorough control over the temperature of the floor the steam flues are divided off into sections; the outside wall of each section is built tight or with close joints, the intermediate

flue walls being built open-work or pigeon-holed, the ends of the brick being about two inches apart.

This is in order that one pipe from the main exhaust may be sufficient for each section. In connection with this portion of the work it must be said the brick should be set in cement, as lime would be affected by the steam.

It is also necessary that consideration should be given to allow for the escape of the condensed water; the under floor of the flues, having been made water-tight by a covering of cement, should have a slight fall towards the point most suitable for the condensed water to escape or be collected in a cistern for return to boiler, which is preferable, as this water is not only pure, but also warm.

These walls are covered with metal floor-plates; a useful size being 24 inches by 30 inches, and half inch thick, or three-eighths would be sufficient when you can get them cast that thickness without twisting. A light rib on the under side of the plate running through the center from each of the four corners will meet this difficulty.

Around the sides and ends of each plate is cast a light flange, extending below the under side three-quarters of an inch. This flange will sink into the cement when placed in the work and help to make a steam-tight joint.

Several attempts have been made to adopt this floor in this country, which have proved failures, owing to the lack of knowledge how to make them steam tight. For successful ones the writer would refer those interested to the Akron Fire-Brick Works, Akron, Ohio, where they can be seen, and as free from leakage as the boiler itself. The flue walls having been built and the tops trued with a string line, the bottoms made water-tight with cement that the water may flow away in place of draining into the ground and damaging the foundations, then proceed to lay the plates by first placing across the flue-walls rods of one and a half inch ⊥ iron the distance apart of the length of the plates. After these have been filled with cement to receive the ends of the plates and the walls covered

with cement for the sides, then lay down the plates, always being careful that the ends and sides of the plates fit tightly together. This full description of laying is necessary, because if carefully adopted it will prevent leakage and render practicable the best dry-floor that can be put down.

The main exhaust steam-pipe should be taken from the top of the water-heater connected with the boiler, and continued overhead through the middle of the dry-floor and across the line of flues, branches from which at the center of each section right and left should connect with the steam-flues.

In each branch is fitted a valve, by means of which each separate section can be made hot or cold or any intermediate state as required. This is one of the advantages which this system possesses; another is that the steam is turned directly into the flues, and has only the thickness of the plate between the steam and the brick being dried; the floor, when the valve is fully opened, being too hot to bear the hand upon. It should be stated that in connecting the exhaust pipe to the heater at boiler into which the exhaust is discharged from the engine, a branch pipe should be connected and passed through the roof; on the top of this pipe attach a sheet-iron lid on hinges, so that in case too many of the valves in the dry-room are closed, the steam will lift the lid and escape, thus preventing any back pressure on the engine.

The advantages of this steam dry-floor over any other, in addition to the control over the distribution of the steam in the various sections as required, and the regulation of heat necessary as before described, are that the exhaust steam is sufficient to provide all heat required for the dry-floor; and should any of the sections require heat after the engine has stopped work, an inch pipe can be connected from the boiler with the main exhaust, and thus utilize the steam left in the boiler.

The main feature, however, is that after the first expense of laying this floor has been paid, the drying of the brick does not cost one cent. The fact that all the brick manufactured

can be dried ready for kiln free of cost should attract and engage the attention of all manufacturers.

Another advantage is a perfectly smooth and level floor, not only allowing the brick and tiles to be straight and true but also preventing the breakage, if not on the dry-floor, in the kiln, in consequence of the brick being not true to shape. One more important feature possessed by this steam-floor over the old system of fire flues is the absence of fire and the risk of being burned out, which so frequently is the case; this should reduce the rate of insurance. It can also be mentioned that in steam-drying everything is clean, there being no ashes to wheel away or accumulate.

Objections have been raised to this plan of steam-drying in consequence of what appears to be its heavy cost as compared with the dry-floors generally used. Do not be prejudiced at first sight. This system is worthy of a careful investigation. Take a pencil and make a calculation in this manner when intending to put down a new dry-floor: first, estimate the cost of this steam-floor as described; that done, get the cost of the old style dry-floor you proposed to put in; then ascertain the cost per month of coal and labor required for the same, and figure out how many months cost of coal and labor it would take if added to the cost of the fire-flue floor to equal the cost of the steam-floor. You would find it would be from twelve to eighteen months, according to the price of your fuel. When that point is reached your cost of fuel and labor continues, while that of the steam-floor is practically nothing, in addition to the many other advantages already alluded to. Economy in manufacture is in doing a little well and reducing the cost of production to the lowest possible point, rather than in trying to spread your limited capital over the largest extent of plant possible. The plan generally adopted in the erection of fire-brick works is for the amount of capital at command to get the greatest output of brick, which means increased cost of production, in place of considering the most modern and economical systems of manufacture, although they may be more costly and the

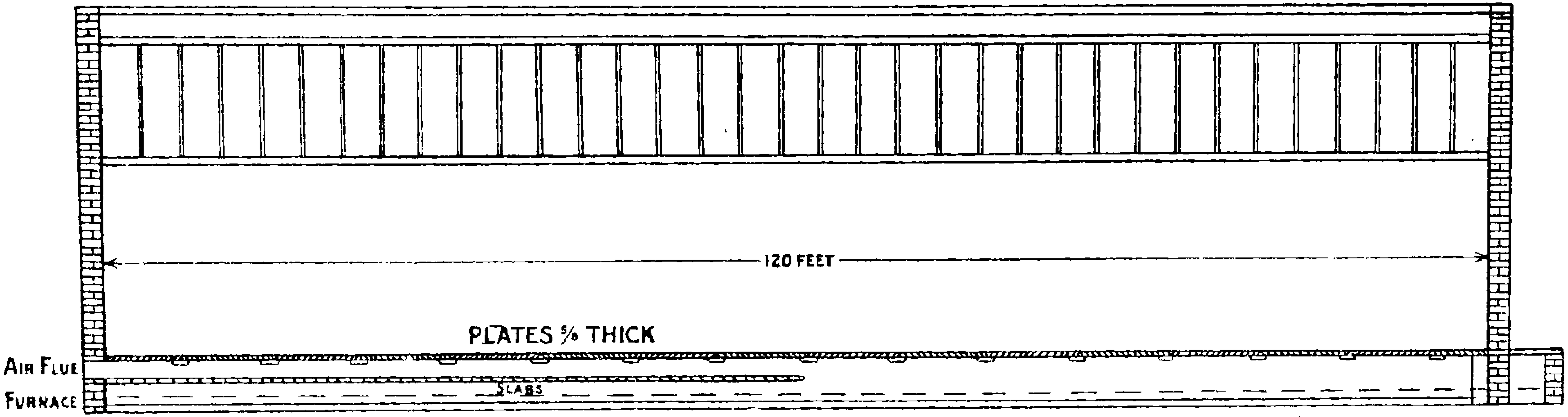
output of brick for the same amount of capital less. Your brick will be of better quality, commanding a larger price, your profits also larger, thus enabling you in a short time to extend your plant on the same principles, and thus you will find you are sailing with the wind, instead of against it as in the former and general way.

Turley & Beyerly's Dry-Floor.—The Kentucky Fire Brick Co., Portsmouth, Ohio, has had in satisfactory use for over a year a drying system in its new fire-brick plant for the drying of all "shape work." The brick made upon this floor are claimed to be firmer, and it is also claimed that the breakage is not five per cent. of the loss by the old process of flue drying. This method of drying fire-clay wares is very economical. The pipes have not in any instance leaked. The circulation and drainage are also claimed to be perfect. This drying-floor is the invention of Leslie C. Turley and William G. Beyerly, of Portsmouth, Ohio, from whom all desired information can be obtained. This brick drying-floor was patented in the United States October 27th, 1891, the number of the patent being 487,554.

Hot-Air Drying Floors.—In Fig. 126 is illustrated a form of hot-air drying floor which is in use in the various plants of the Glenboig Union Fire Clay Co., Limited, of Glasgow, Scotland, and which is suitable for the drying of either fire-brick or sewer pipe.

It enables a manufacturer to put two moulders in the space usually allotted to one, and it completely does away with the "hot end" and the consequent cracking of goods dried near the firing ends. At Glenboig they use iron plates (flasked castings), each 4 feet by 2 feet by ⅝ inch, but fire-clay covers (slabs) can be used. These plates are secured in position at their joints on cross-plates, whose breadth is about that of a brick, and by this arrangement all possibility of dust geting through to choke the subjacent fires is effectually prevented. Besides the increased production from a given size of drying-floor, the firing is safer and more regular, and the first

FIG. 126.



LONGITUDINAL SECTION OF DRYING FLOOR.

cost is greatly reduced, as air space takes the place of fire-clay slabs in a large portion of the floor. The illustration in Fig. 126 gives a good idea of the construction of the floor.

These drying floors, or "drying stoves," as they are called in Great Britain, are each 120 feet long by 36 feet wide.

Although the stoves are fired from one end, there is a uniform temperature maintained in them throughout their whole extent. This result is accomplished by having an arrangement of double floors, with cold-air passages between them half way up the stove. By this system of heating Mr. Dunnachie obtains the most perfect control of the temperature of the stoves, even though an iron floor is used, an object long aimed at and often attempted, but now successfully accomplished. In ordinary practice there is no deterioration of the brick. No overheating takes place, consequently no cracking of the brick, and therefore they go far sounder to the kiln than is usually the case. Owing to the special mode of arranging the dampers, each stove can be worked in stripes, to be strongly heated, if necessary, or mildly when sharp firing is not desirable.

Owing to the successful way in which the drying operation is conducted, those brick which are made one day are ready the next day for the kiln, whither they are at once carried direct without any piling. As there is thus no unnecessary handling, the chipping or other injury which brick frequently meet with while unfired or in the green state is reduced to a minimum.

The air-flue at front is closed by a slab, which is tilted around so as to make the opening large or small, as may be required. This is a better and cheaper arrangement than a close door.

Some of the older fire-brick works in the States of Ohio and Pennsylvania have in use hot-floors, which are constructed as follows: Across the end of the floor, which is nearly always rectangular, is dug a pit some six feet below the general level. In the wall of this pit are set fireplaces at intervals of from five to six feet. The fireplaces proceed inward about a yard, and then break up into from three to five parallel flues. These

flues are about ten inches square, and are separated by four inches of brick. The flues traverse the whole distance of the floor and unite in a chimney or chimneys at the other end, which must be high enough to make every individual flue draw. These flues are covered by square tile twelve inches on a side; the tile are placed four thick at the fire end of the flue, and run down to one tile at the opposite end. This is done to equalize the heat of the floor. The depth of the flues is so arranged that their unequal covering brings the tile to a level plane; on this is spread a cement adapted to this use; it is made of basic furnace cinder and sandy clay in equal parts, ground fine, and wet. If the cinder is not basic enough, lime is added; the mixture sets very hard, and will last four or five years if well treated. Sometimes the flues are covered with one thickness of tile all over, and are then leveled up with sand and another layer of tile. This is undoubtedly cheaper, and is also as even a distributor of heat as a plain tile floor would be, but is rather more apt to cause trouble in repairing by blocking up the floors with sand.

Conveying Fire-Clay. The most economical and expeditious methods of handling fire-clay at the mines, and conveying it from the mine to the factory, are of great importance, as the continuous operation of work during both winter and summer often depends on the means used to transport the clay.

The Union Mining Company, Mount Savage, Md., has had much experience in the handling of fire-clay. The clay mine of that company is situated on the south side of Savage Mountain, three miles from the works by the tramroad. The bed of clay crops out along the summit of the mountain, and runs nearly northeast and southwest. The only other mine on this bed is a very small one, two miles from that of the Union Mining Company. The clay from this mine is brought to Frostburg, where it is manufactured into brick.

The large bed was first opened on the out-crop, and for a number of years all the clay was dug from open pits, and hauled at great expense down the mountain in wagons to the

works. Finally, when this method of mining had been carried on as long as was economical, the mine began to be worked systematically, and the levels were driven on the out-crop, on one side, wherever it could be reached by reason of the formation of the hill. From this level, galleries were driven at an angle up on the bed, clear through to the old workings. Chambers were driven out from these galleries, connecting the galleries as often as the ground would permit. When these chambers are all driven through, that part of the mine is robbed of as many of the pillars between the chambers as it is practicable and safe to remove. There are several of these levels driven, the last one about 100 feet below the next above, and as the bed dips about one foot in every four on an average, one can calculate on the amount of clay each level will yield. From the present outlook there is enough to run the works for a great many years.

At the time this more systematic mining was begun, some cheaper mode of transportation was also sought. First, a wire-tram on the English system was tried, consisting of an endless wire rope, with buckets of the capacity of fifty pounds, and a stationary engine of 80-horse power at the bottom. This plan involved much trouble, and never could supply the requisite amount of clay; and when winter came, with its extreme cold and snow, the plant was practically useless. Then the regular three-rail incline was adopted, which is in common use in this coal region, and which has worked well ever since. The only peculiarity of this incline is its great length. It is a mile and a quarter long, and the rise from the bottom to the top is 1,240 feet. Six cars run up it at a time; three loaded ones coming down haul up the three empty ones. The rope is of steel, and five-eighths of an inch in diameter, and runs over two shrive wheels twelve feet in diameter, on each of which is a hand-brake. One man to run these brakes, two men to load, one man to unhook at the bottom, and one to look after the rollers on the incline, are all that are necessary to run 100 tons of clay per day. The cars when empty weigh 1,800 pounds, and two

tons of clay are loaded on each car. It takes seven minutes, on an average, to run one trip. This is said to be the longest gravity road of its kind in the world. From the bottom of this inclined plane a tramroad is built, two miles, to the factories at Mount Savage, and a substantial narrow-gauge locomotive placed upon it brings all clay direct to the factory, where it is dumped in the extensive yards, convenient to the grinding-pens.

The coal which is used at the works is obtained on the property from the coal measures above the clay. It is mined from a vein twenty-two inches thick, and is brought down to the head of the tram-road by a short incline, and there it is run in with the clay, and trains made up of both are run down to the brickyard.

Not all fire-clay works would, of course, require such extensive facilities for handling and transporting clay as are necessary at Mount Savage, Maryland, but wherever it is possible horse and mule power should be abandoned.

As steam has taken the heavy work of transporting the products of the country from the horses which formerly did the overland hauling, so it is doing now in the brick factories.

The apparatus for drawing the clay into the factory by the engine being in the first place cheaper than horses and carts, and doing the work without a driver, besides not being at expense when idle, it was a natural result that the winding drum and automatic dump-cars were adopted by all enterprising brick manufacturers.

To suit different demands, manufacturers of brick-making machinery usually construct two sizes of winding-drums and dump-cars, which are self-contained in substantial iron frames and which can be operated by a cord from the clay-pit or by the engineer from any point in the factory.

The frames of these machines are so constructed that they can be bolted to the upper part of the track timber, which does away with extra framing for that size. The pulley on No. 1 machine is 36x8 inches, and should be run 450 revolutions per minute.

Weight of No. 1, with 400 feet of iron cable, 1300 pounds.

The manufacturers commonly build two standard sizes of dump-cars of good heavy timber, well ironed, and arranged to dump automatically when desired.

No. 1 dump-car holds 1½ cubic yards of clay, while No. 2 has a capacity of but one yard of clay; light wrought-iron T rails are employed for the cars to run on, the width of track between centres of rails being forty inches.

The bottom of the dump car is usually in two parts, hanging on chains which are attached to a bell-crank, which is keyed to a steel cross-shaft that has a lever on the outside of the car, which is held in position by a catch that hangs down between the wheels near the track. A stop fastened to the track releases this catch and lets the bottom drop, when the car runs back, and the diggers by a pull of the lever again place the bottom in position. This is done very quickly. Side dump-cars, arranged to dump on one or both sides, are also built to suit different localities, by The Frey-Sheckler Co., Bucyrus, O.

FIRE-BRICK MANUFACTURE

See FIRE-CLAYS, under head of CLAY in Chapter II. The details of manufacture and the equipment of plants for the production of fire-brick vary with circumstances and the kind and variety of brick to be made, which may range from the smallest nine-inch shape, weighing three pounds, to the largest glass-house shapes, weighing 3,500 pounds or more.

The manufacture of fire-brick, from the mining of the crude clay to the delivery of the finished goods from the kiln, is a succession of processes simple enough in themselves, and easy enough to those who are thoroughly skilled in the trade, yet involving great care and incessant vigilance in order to insure continued success.

Both a practical and theoretical knowledge of the business is highly desirable, if not absolutely necessary, in the person who assumes the active management, be he proprietor or hired manager. By practical knowledge is not meant that he should

have the physical ability to go and take a moulder's or presser's or setter's place and do a day's work. But a man in this position should be so practical as to be able to tell at a glance whether a brick or piece of shape-work is made properly or not, and if not, what is the matter with it. He should be able to tell as soon as he feels of the tempered clay whether it is too soft for the work for which it is being used, whether the kiln men are setting the brick and shapes to the best advantage, whether the firemen are firing a kiln right or only putting in the time, whether a kiln has heat enough or needs to go twelve hours longer. He should be able to tell when he comes into the works by the sound of the machinery whether it is running all right or not. These, and a hundred other things, to the "practical" manager should come as natural as life. If the works are of any extent, so that he has a foreman under him, he may not have to notice some of these things once a month, or longer, but he should possess the knowledge, and when least expected it will serve him in good stead. He may or may not be able to handle men to advantage; if not, he will see to it that he gets a foreman who has the knack of doing so, for it is a gift all men do not possess. Theoretical knowledge means a great deal more than might at first thought be supposed. If a man as manager or general superintendent is ambitious of attaining the highest results he needs to become acquainted with the following branches of science: Chemistry, geology, mining, mineralogy, metallurgy and mathematics. Chemistry will teach him the composition of clays, the specific influence for good or evil of one element upon another, the correct selection and mixing of clays to make fire-brick suited to different uses. Geology will teach him all that can be known of the formation and origin of clay beds, and also where to prospect for the clay he may be seeking, according to the different formations. Mining will teach him how the clay can be mined profitably, economically and without waste of clay territory. This department, however, is often taken out of the hands of the manager of the works and given in charge of a competent mining

engineer, especially where, as in many cases, the miners are at some distance from the works. Metallurgy teaches the different processes used for extracting metals from their ores and the mode of manufacture of the various metals, and thus shows the requirements, sometimes special and extraordinary, of fire-brick for use in different processes, with the effect upon them in various positions and at different temperatures. Mathematics is of great use to the manager in calculating the sizes and shrinkages of difficult shapes.

These subjects enter into the theoretical knowledge which a manager does well to have. Some are of less importance than others. Chemistry and metallurgy are almost invaluable, showing as they do on the one hand the causes which tend to the destruction of the brick under diverse conditions, and on the other hand how to make brick that will present the greatest resistance to destruction, by a proper selection and mixing of clays. Such knowledge will save a man from many costly mistakes into which he may otherwise fall.

In the manufacture of fire-brick the correct choice of the raw materials is the basis of success. The methods of working vary in different countries. But as the refractory clays present very dissimilar properties, and these dissimilarities show themselves in various grades and differences in quality, a factory where a great variety of products is to be turned out should not be restricted to the working of but one bed of clay. A free and unrestricted choice of material, on which the value of the product is necessarily dependent, must always be considered as a special advantage in locating a factory. In working crude clays it is, however, almost always necessary to add chamotte, or, as a substitute for it, old fire-brick and fragments of worn-out clay vessels (glass pots or seggers, crucibles, muffles, etc.), whereby the mass gains in density, resisting capacity, solidity, inalterability.

Storing, Weathering and Elutriating Fire-Clay. The piles of clay from which the selection of clays for mixing is made, usually adjoin the works as closely as possible on the side next

to the grinding machinery. In many places the amount kept on hand is large, amounting to 7,000 or 10,000 tons. There is no object in thus storing fire-clay, unless it be either to insure a supply for some time in advance and guard against transient interruptions, or to allow the clay to slack and break up fine, thus curtailing part of the mechanical preparations otherwise needed. There is a belief largely current that allowing a clay to be exposed to the influences of the weather acts advantageously in ridding it of impurities. Though it cannot be denied that under certain conditions this would be so, yet it is equally certain that these influences are much overrated. The impurities which would thus escape are potash and soda, from such compouds as feldspar and mica; yet the decomposition of these minerals having been effected by weathering, the mechanical conditions which would aid in the escape of the impurities are seldom found. A strong slant to the floor of the clay pile, so that water would drain away quickly and well after raining, and only a thin layer of clay on the floor so that impurities from the top layers might not lodge in the bottom, would favor the escape of impurities; but the exact opposite of both these conditions as a rule prevails. Iron sulphide and carbonates of lime and magnesia would also tend to decompose and leave the clay, but their action would be very gradual. But the mechanical subdivision of the clay which takes place is undoubtedly advantageous; alternate frost and heat has long been reckoned as a valuable agent in increasing the plasticity of hard clays.

Some clays, however, are naturally highly plastic, a condition which detracts from their refractoriness, and as weathering promotes plasticity it does not improve this class of clays. Clays of the non-plastic type and those that are very hard when freshly mined should all be weathered before using. It takes off that rawness noticeable in freshly-mined clays of this class, conduces largely to an increase of purity, renders the clay much better to temper and easier to work, and makes sounder, better brick. It also facilitates the sorting out of im-

pure matters that have escaped the miners, and also makes it easier to grind, thus reducing the wear and tear and increasing the capacity of the plant. To obtain the full benefit from weathering, the clay should be kept exposed some months ahead, and not stored in large heaps, except it be turned over periodically, or much of the benefit will be lost. In storing the clay it should be arranged so that it can be used systematically and in order of its age.

A more effective but also more artificial means of improving fire-clays is by elutriation, the separation of heavier and coarser particles of iron combinations, sand, quartz, etc., being best effected thereby. Besides, the elutriating waste, especially when elutriation is preceded by an organic disintegrating process, carries away the alkalies as well as a portion of the silica in soluble form. The treatment of the clays with acids should be entirely rejected; therefore the only practical means for improving the clays which can be recommended are weathering and elutriating, and only these means have come into use in manufacturing on a large scale.

Calcining. A certain portion of the clay used in the manufacture of refractory materials is calcined and converted into "chamotte" or cement. With some clays calcining is a prime necessity. These clays are such as are highly plastic, and if made into brick entirely from the raw clay, form a dense, close body, predisposed on that account to incipient vitrification, and will not stand sudden and extreme changes of temperature. By using from one-third to one-half of calcined clay a granular body is obtained, and the defects just mentioned are overcome. From this necessary method with plastic clays, the practice of calcining has also become quite common in treating the flint or non-plastic clays.

The most important constituent of all refractory wares is the calcined clay or "chamotte." This will not shrink, and possesses the power of union in the greatest possible degree. These two important qualities have more to do with the production of fire-clay goods, regular both in size and in quality, than any other features in the material or process employed.

Another advantage in calcining clay is that it enables one to throw aside any material in which there are impurities that may have been previously overlooked, since these are much more easily seen when the clay has been burned. The proportion of calcined clay or "chamotte" used must, of course, vary with the size of the brick or tile, and the particular use for which it is intended.

In calcining fire-clay, the raw clay as it comes from the mine or pit is used, and of this the lumps are preferable for this purpose. The reason for this is that the small or fine clay is more trouble to handle and to burn. The lumps can be more easily placed in the kiln and the fire can get a draft through between them. Of course a certain quantity of small or fire-clay can be used along with the lumps. Two points here should be observed. First, it should be dry when set, or it will be liable to fall in the kiln and obstruct the draft. Second, it should also be freshly mined, as, if exposed to the weather too long it falls to pieces and cannot well be handled. These remarks are intended to apply more particularly to the clays of the coal measures, which are either non-plastic or plastic, and which come out of the mine in hard blocks. The soft plastic clays, either fire-clays or terra-cotta clays, that can be dug out of the bank in large pieces or blocks, must be dried before being burnt, and can then be treated in the same way as just described.

Some manufacturers of refractory materials have the clay intended for calcining cut in twelve-inch lengths as it emerges from a 6x6 inch hole at the bottom of an ordinary pug-mill, and then set these crude blocks of fire-clay next to the walls and in the same kilns in which the wares are fired. These rough blocks thus calcined are, on removal from the kiln, broken by a six-stamp mill, and afterwards ground to three or more degrees of fineness in ordinary grinding mills.

The more advanced fire-brick makers, however, have separate calcining kilns, which are built of brick, with a boiler-iron shell, as will be described. These kilns in large works are com-

monly 15 feet high and 8 feet in diameter, with fire holes a few feet from the bottom. The top is dome-shaped, with a chimney from the centre having a damper on top. The clay is charged in through a hole near the top of the dome, and is drawn out at the bottom of the kiln on iron plates, through two drawing-doors, one on each side of the kiln, 20 tons being the daily product of one kiln.

"Lean" Materials.—Very few clays can be used as mined. They must be, as it were, suspended in some infusible material which will prevent, as far as possible, the mechanical effects of the heat, and allow, at the same time, of a certain amount of expansion and contraction, while preventing both in too great a degree. These materials are generally called "lean," that is, they do not make a paste with water, and require some binding material to keep them together. They are usually quartz-sand or pulverized quartz, burnt clay, old brick, serpentine, talc, graphite in powder, and not infrequently small coke, when the ash is not to be feared, and when graphite either cannot be had or cannot be used on account of its high price. Some fire-clays from Spain contain this "lean" material, which comes from the decomposition of talc-shale in which they have been suspended by nature, but this is a rare exception. The mixture must generally be made artificially. Of all these substances quartz-sand is the cheapest, but it has been found by experience that round grains of sand are less liable to become thoroughly incorporated with the binding material than the angular pieces of crushed quartz, so that when a very refractory material is required crushed quartz is always used. As the clay contracts and quartz expands, a mixture may be made which will not change its form; but in a given case this may not be the best mixture for a special use. If the material has only to resist a great heat, an excess of quartz is preferable; but if it must also resist the corrosive action of basic slags, clays burnt at a high heat, graphite or coke, can be used. When the mixture is made in the place where it is to be used, without previous burning, it is generally made of one-fifth plastic clay and

four-fifths burned clay or quartz, or one-fourth lean clay and three-fourths burned clay or quartz. This is done to avoid contraction.

When chamotte is used (*i. e.*, fire-clay previously burnt and comminuted) the material for the chamotte is comminuted by grinding, and consists partially of clay as refractory as possible, especially burnt for this purpose, and of worn-out glass-pots or seggars, crucibles, muffles, and other waste of refractory clay articles. The more refractory the clay, as well as the chamotte used, the more refractory the brick will be.

The finer the grain of the chamotte the more of it may be added to a clay, whereby the mass gains in homogeneity and strength, but, on the other hand, loses in capability of bearing changes in temperature, and inversely, the coarser the grain of the chamotte, the better the composition will bear rapid changes in temperature. It is best to endeavor to unite both properties by adding to the quite finely ground crude clay a mixture of finely and coarsely ground chamotte, taking a somewhat larger proportion of the latter. As a rule the coarse grain should not exceed one-quarter inch in size.

The proportion in which the burnt clay or the substitute for it is mixed with the crude clay varies according to the degree of fatness or cementing capacity of the latter. If the cementing capacity is considerable, for instance, about 10 to 12, as in Belgian clay, and the chamotte is sharply burnt, which is necessary for the production of good brick, 1 part of crude to 2 parts of burnt clay is used. If, however, the crude clay is quite meagre, and possesses but little cementing capacity, for instance only = 3 to 5, the addition of chamotte must be considerably smaller in order to obtain a mass of sufficient plasticity and suitable for transport, and the proportion may be reduced even to 1 : 1—*i. e.*, 1 part of burnt clay to 1 part of crude clay. If the rule to use the most refractory clay at the disposal of the manufacturer, as chamotte, is to be considered as valid, it follows that nearly everywhere the fat clays should be used for the crude portion of the composition, and the meagre clays, which are

frequently more refractory and generally burn very hard, for the burnt portion, since the refractoriness of the entire mass is thus increased by the greater addition of burnt clay required. Variations from this rule will, however, be sometimes necessary, according to the different pyrometrical value of the clays at disposal.

Mixing Fire-Clays.—It is in the mixing of the clays used in the manufacture of refractory materials that the skill of one operator over another is manifested.

Clays which are to be used in the manufacture of fire-brick and other refractory materials, after being stored in the sheds, cleaned, and carefully dried, and in all other ways properly prepared, are afterward mixed with the substances with which they are to be incorporated, which are classified by numbers, varying according to the size of the sieve-holes through which they will pass. The quantity and quality of the mixture will determine the refractory nature of the material to be produced. A friable paste with large grains, and quite porous, resists a great heat. One with fine grains, close and compact, splits at a high heat, especially if it is not homogeneous. The manner in which the mixture is made also influences the quality of the brick quite as much as the material. In some works in Belgium, after taking all the ordinary precautions to make the mixture perfect, it is submitted to a succession of shocks continued for some time, until it is found by experiment that the materials are perfectly mixed. It has been found by long experience that the brick so made keep their form perfectly, while others made of exactly the same mixture in the ordinary way contract. The quantity and size of the mixture depend upon the size of the article to be manufactured. When coarse grains are used, greater thickness must be given to the sides of the articles if they are hollow, and they must be made larger if they are solid, thus giving a mechanical cohesion where a chemical one is wanting. The usual quantities of the mixture for brick are three-fifths to two-thirds of the substances added to two-fifths to one-third of the clay, these quantities being

determined by volume and not by weight. When coke-dust is used it does not seem to have any decided effect beyond one-tenth. The action of coke or graphite is to decompose the metallic oxides as they form, and thus prevent their union with the material of the crucible. Coke may be profitably used in the place of graphite when the ash is in small quantity, free from iron and highly aluminous. Beyond 2 to 3 per cent. of graphite cannot be profitably used, as it weakens the article and renders it liable to break. The mixture which gives the very best results for small articles is, however, worthless for large. It will generally be found that the pieces which crack up and down in drying have had too much material mixed with the clay, and those which crack laterally have had too much clay.

The very greatest importance is attached in some industries to not having a mixture made by a machine. In many places even to this day the inhuman method of heel-treading is used, because more care is then exercised, or because smaller quantities being mixed at once, better results are obtained. The more the operations of mixing are repeated the better the material, and it is undoubtedly true that with mechanical means such a homogeneous paste is not produced as can be made by human labor, because the whole object of the machine is to operate on large quantities at a time.

Every mixture has its own peculiar rate of expansion and contraction. This expansion not only takes place when the brick are made, but if when used they are submitted to a higher degree of heat they expand still further, and contract again on cooling to such an extent that at Dowlais, Wales, the tie-rods of the steel furnace are slackened when the furnace is getting into heat, and are tightened again as it cools. At Crewe, England, this is made self-acting by means of springs. At Creusot the furnace-casing is made so strong as to resist the pressure, so that the roof-arch must rise and fall, to allow for the expansion and contraction. When neutral brick must be had for any reason, it is mixed with just enough clay and burned brick to

make it keep its form, and such a brick is generally less fusible the less silica it contains.

The proportions of flint, "lean," calcined and plastic clays which shall compose the brick or other fire-clay product having been determined, the materials are selected from the pile; the mixture of so much of each factor is made by counting the shovelfuls with which the charging barrow is loaded. As a rule no closer proportion is kept anywhere than careful shoveling will make. In the manufacture of silica brick, however, the most scrupulous care is necessary, and it is the practice to carefully weigh the constituents, platform-scales being used upon which the loaded barrows are run.

Washing. The barrow being loaded, the clay, be it plastic or non-plastic, should be washed. The washing is accomplished by running the barrow over a sink or drain and drenching from a hose above. The barrow being perforated on the bottom speedily drains dry again. This treatment, though not thorough, tends to free the clay from dust, mud and dirt, which stick to it from the diggings. The best method of washing is at the excellent works of the Harbison & Walker Co., Pittsburg, Pa. Their machine consists of a cylinder revolving in a slightly inclined position in a trough of water. The wall of the cylinder is made of coarse iron gauze or netting, and on the inside is bolted a spiral flange beginning on the upper end and running to the other extreme. A charge of clay is introduced into a hopper at the upper end, and by the flange is slowly carried down the length of the cylinder, being agitated in water, which is about six inches deep in the lower part of the cylinder. This machine is only used to wash hard, uncalcined clays, for the plastic grades would not stand so severe a treatment, and calcined clays do not need it. Washing is only useful or advisable where the hard clays in use are mined by benching or stripping and come to the works covered with mud or dirt.

Grinding and Tempering. We may now follow the clay through the successive steps of grinding, tempering, molding, pressing, drying and burning.

The correct mixtures of the constituents of fire-brick having been accomplished, it is necessary in the further working of the mass, when moistened in the proper proportion with water, to be especially careful to obtain complete homogeneity in the interior of the brick, and the utmost mechanical strength. This is attained by a thorough and intimate kneading of the mass, by firmly pressing it into the moulds and by slowly drying the moulded brick. By over-hastening the drying the mass is again loosened, which injures the quality of the brick as regards mechanical strength.

For most uses in practice a high degree of mechanical strength is demanded from fire-brick, which depend for their refractoriness upon the nature of the clay used in their manufacture. With comparatively less refractory clays showing an inclination towards slagging at a not very high degree of heat, the ordinary burning, which is the final operation of manufacture, frequently corrects any carelessness committed in working the mass, the brick after burning appearing sufficiently strong and hard. With very refractory clays this is, however, not the case, since they do not readily slag in the heat of an ordinary kiln. For these, sharp burning, which is absolutely necessary, must be preceded by the most careful and thorough working of the mass, and, if possible, a strong pressing of the brick moulded by hand.

The grinding of the clay has been attempted by various methods, including crushing-rolls, pulverizers and disintegrators of various kinds, and by other mechanical appliances. For hard clays none of these have proved successful, and the only method to give satisfaction is the grinding-pan, either wet-pan, dry-pan, spiral pug or chaser-mill. The latter is not much used now for grinding clay for fire-brick making, although it is a very suitable machine for some other branches of clay-working. The method of preparing the clay depends largely on the mode of manufacture adopted. Up to the present time the moulding of fire-brick is almost entirely accomplished by the hand-method, which requires the clay to be tempered and made up quite soft.

There are three distinct methods of accomplishing this, viz.: The wet-pan process, the dry and wet-pan combined, and the dry-pan and pug-mill combined. The methods of grinding and tempering are somewhat various. The "Fire Brick Mill," as used in England, is unknown in the United States.

The methods in use in America are the wet-pan process, where the grinding and tempering are done together in a solid bottom pan; the dry-pan and wet-pan combined; and the dry-pan and pug-mill combined. Other methods of grinding, such as the "ring-pit," for example, have from time to time been tried, but have failed of adoption to any extent.

The wet-pan is found in most common use where a hard, flinty clay and considerable calcine are used. In charges containing considerable amounts of both these bodies and only a little plastic clay, such hard and intimate mixing is the only way in which the structure of the brick can be made sound. This wet-pan process is used entirely in the Sciotoville district. Ironton and Logan, Ohio. The clay is dumped into the pan in the rough, water is turned on, and the charging is ground and tempered until the attendant judges it to be fine enough. There are some objections to this method of preparing fire-clay, as it is next to impossible to get the clay of a uniform grain, as some of it is ground too fine, while another portion may be too coarse. Then, again, the process is slow, and for an extensive works a great many pans are required to prepare enough clay, the usual quantity for each pan being a day's work for one moulder, which consists of 4,000 brick, with a few extra thrown in for waste. The pan is usually fitted with a pipe from the engine, from which water can be had by turning a faucet. Either hot or cold water may be used; it probably makes no difference which, in the quality of the brick, but the former makes the work of the moulder much more endurable.

The wet-pan method has one great advantage which is not possessed by either of the other processes, and that is that each moulder may be on a different grade of brick, requiring a different mixture of clay; and by having a wet-pan to serve

each moulder, several different mixtures can be in preparation at the same time, whereas in either of the other processes only one kind can be made at once, and, therefore, all the moulders must work on the same grade of brick.

In the dry and wet-pan combined, the tempering is done in a wet-pan.

As the clay has been already ground by the dry-pan, a few revolutions of the wet-pan are sufficient to mix the clay with water and bring it to a proper temper for moulding. The clay is usually taken out by hand, either with a loose, ordinary spade or shovel, or by a level-shovel fixed for the purpose. A special style of pan is used by the Union Mining Co. of Mount Savage, Md. In this pan the rim is loose and does not revolve. In the rim is a gate which opens into the pan. When a charging of clay is put into the pan and is sufficiently tempered, the gate referred to is opened and the clay is automatically discharged, and the pan is then ready for another charging of clay. This is an ingenious plan and a great improvement upon the ordinary pan. The clay after being prepared is carried to the tables of the various moulders by an endless belt, where the brick are to be moulded by hand.

The dry-pan and pug-mill mixer combined is the style of grinding and preparing fire-clay least adapted to general use of all three ways, but is a cheap and useful method in some cases. The pan is very similar to the ordinary wet-pan, but has this difference: the floor is fitted with plates cast in segments fitting on a framework of radii beneath the pan. The plates are thus fitted into a level and continuous floor; they are full of parallel slots or holes, which open immediately into a larger room from the underside, so that any particle of matter which passes the surface will have no chance to stick lower down. Beneath the pan is a bin into which the clay, as fast as it is reduced fine enough to pass the bottom of the pan, falls; in this bin revolve arms, which collect continually the powder and deliver it at the foot of an elevating-belt which is at one corner of the bin. The charge is all introduced together and is run until

it has all disappeared beneath the surface, or else its proportion of calcine would not be equally distributed. All dry-pans are subjected to this disadvantage, that the softest parts go through first and the harder last, so that the powdered clay as delivered by the elevating-belt would not be strictly homogeneous; also, the largest part of the clay goes through at once, and the longest part of the grind is devoted to getting the least of the charge through, which is a waste of energy. Another disadvantage resulting from this plan is the fact that the hard material is never rendered finer than is necessary to pass the holes in the floor, which to make the machine work at all rapidly are necessarily larger than is good for the brick. The powdered clay having been delivered into a bin above, is ready to be mixed as needed. The mixing-machine is a trough about eighteen inches wide by eight feet long by eighteen inches deep; in it works a horizontal axis on which are fixed cutting-arms, which are arranged spirally, but at such a pitch that their action is slow in moving the clay forward. The tempering is done by merely adding clay and water, and allowing the machine to mix it up to a paste.

In the case of plastic clays, an open mill or mixer may be used, but for non-plastic clays, or where considerable calcine is used; it must be a closed pug-mill of good length in order to get the clay sufficiently tempered for moulding.

A process of grinding and tempering fire-clay which is much in favor in the older river works of Jefferson county, Ohio, and also at Mineral Point and Haydenville, Ohio, is theoretically the most correct of all methods in use; but it is also the most expensive as well. Along the river the clays used are as hard and rocky as sandstone when they are newly mined; they are sandy and apparently non-plastic, but by this treatment they develop into one of the best working clays in the State of Ohio.

The dry-pan used is of the kind previously described, and is adjusted to deliver the ground clay into an elevator. This carries it up to the top of the building and delivers it upon a screen. This screen is a box about fourteen feet long, by four

feet wide, by seven feet deep; the bottom of this box is made of sheets of perforated sheet-iron, the holes about one-tenth of an inch in diameter; the slant is about 45 degrees, so that whatever enters the screen is sure to leave it either by passing through or by running off at the end. That which escapes from the end is carried down by spouts to the dry-pan, and is re-ground, so that a charge being introduced runs on until it is all through the sieve. That which passes the sieve is caught by a cloth or board hopper beneath, and is conducted to the tempering mill or to the bins for storing. The clay which has been screened is beautifully fine and even. The tempering mill is on the same principle as the wet-pan first described, but is of a larger diameter; the rolls are frequently arranged to turn instead of the pan; they are of larger diameter and less thickness than the wet-pan rolls, and weigh usually 1,800 pounds each. The pan is provided with water, and a charge is thrown in wet and ground briskly until as plastic as can be; by this course of treatment the qualities of the clay are developed to the best possible effect.

Moulding and Pressing. In England the brick are all made of very stiff clay, in brass moulds, and are not pressed. They are perfectly solid and square, and in fact need no pressing. This method has not been adopted to any extent in the United States. The almost universal method employed in this country is to make the brick in wooden moulds, using very soft clay, or "mud," as it is technically termed; then to spread the brick on a warm or hot floor to stiffen, and then press in a hand lever press, and return to the hot floor to finish drying.

The object of pressing is not so much to make the brick dense as to square them up and put them in better shape. This method of moulding fire-brick is followed in every section of the country, East, West and South, and will probably continue to be largely made in this manner for some time yet to come. In some of the older works the brick are moulded in iron moulds, the clay being tempered in "ring pits;" a day's work in such plants being to mould and press 1,200 brick, the

men wheeling their own clay from the pit to the moulding-table; a gang comprising a moulder, presser and off-bearer. Hand-pressing is almost the universal rule, but there is a demand for something better. This is now at hand in one or two steam-power presses that are powerful, simple and easy to operate, and which effect a saving of at least half of the cost of hand-pressing. At the same time it is often claimed that there is no advantage in steam-pressing; that hand-presses can be moved about to suit the work, and are handier, etc. There is a semblance of truth in much of this, but when really sifted down there is very little in it. No account is taken of the time that is taken up in moving the press around, nor of the fact that the brick have to be moved from the warm, or stiffening floor, to the hot, or drying floor (of which more anon), and hence but little more moving is required to press than on a stationary steam press, and with the different system that can be adopted, the saving in cost is as above stated.

In the fire-brick factories of St. Louis, Mo., there is in use a somewhat different method from the above. There the clay or mud is made very stiff and moulded direct into the press-box of a press, and when it leaves the press is finished ready for drying. Of course a man cannot make so many brick, not over about half the quantity; but the saving of so much unnecessary handling, and the saving in room required, make a decided reduction in the cost of the brick. This, of course, is confined to nine-inch work, or at most, to 13½x6 furnace blocks. All large shape and special work is of course made in wooden moulds by hand, and the writer is inclined to think from practical experience that there is hardly likely to be any change in the method of making this class of work. In the various forms of nine-inch work, however, which forms the staple of the fire-brick business, machinery has been introduced which seems likely to effect a revolution in the trade. This is emphatically a mechanical age, and its influence has long been felt and acknowledged by every other department of clay manufacture. Fire-brick makers, however, have been content to still go on in

the old humdrum way, and the moulder laboriously makes his clot, or warp, or pone, and whacks it into the mould. Fire-brick makers, as a rule, have settled down to the idea that they will never be made any other way as long as the world stands, and few of them will even listen to the idea of making by machine. In fact, there has always been a decided notion that they cannot be made except by hand moulding. But all this is no argument, and it should not be forgotten that similar opinions have been held upon many other things in regard to the adoption of machinery. It must be confessed that many failures and few successes have attended all attempts at machine-made fire-brick in the past. But every failure, if carefully observed, is one step nearer to success.

Mr. Joseph Cowen, of Newcastle, England, says that in the North of England (Northumberland and Durham) attempts have been repeatedly made to produce fire-brick by machinery, yet without success; whereas in Wales such an application has succeeded, owing, it is suggested, to the Welsh clay differing in quality from that of the North; and in his opinion fire-brick will continue to be made by hand. Machine-made brick, he says, are always more compact than those made in the old way, and this he considers a defect. Mr. Cowen here probably strikes the keynote to the cause of most of the past failures in previous efforts to make first-class fire-brick by machinery.

The question of moulding without pressing, as in England, and that of moulding and pressing, as practiced in this country, is worthy of consideration, hence the writer will give particulars of the English process and reasons why.

The clay is prepared as stiff as it can be worked up by the hand of the moulder into a solid warp or ball ready for the mould. As he raises it from the table it will be found to be regular in form, the shape of the mould, only smaller, so that it will go in quite clear and spread out to the sides and ends of the mould. The moulder raises it up well and throws it into the mould quickly and with force. The moulds of one brick

each are cast of brass, light and thin, with stronger flange round the wearing parts, that is, the top and bottom. The moulds being open, between these two flanges light oak sides or strips are placed, running about two inches past each end, forming lugs for the off-bearers to handle them. These ends are rounded off, and a small iron bolt is riveted through each pair of ends, making the whole tight and firm. The moulder will, after delivering the clay into the mould, strike off any surplus clay, sprinkle on a little water, then again run his striker or planing-board twice over the surface, giving it a perfectly smooth and finished appearance. A boy then takes the mould from the table and delivers the brick on a pallet which is placed on a small bench by his side. The second boy or runner comes up to the bench with pallet in each hand, lays one on the bench and places the other on top of the brick, picking up the two pallets with the brick between, which at the same time presses down any bead left on the brick in coming from the mould; he runs off with it and places it on edge, the same as when taken from the press.

The mould being of perfectly smooth brass requires neither sand, water nor oil, and the ball of clay being properly prepared by hand and well thrown in, the brick comes out with a perfectly smooth skin, as from the press.

In this way of moulding the cost is exactly the same as moulding and re-pressing in this country. In the former a man and two boys mould 2,000 brick for a day's work, in the latter a man and two boys mould 2,000 and press them. It may be asked, Where, then, is the advantage? It is in the uniformity of the density of the body and the perfect regularity in thickness, a matter of great importance in fire-brick manufacture and a regular cause of complaint where brick are re-pressed. This irregularity of thickness in re-pressing is principally caused from the brick when moulded and placed on a dry-floor which is hotter in some places than in others, and also that the brick last made have been on the floor longer than those first made before going to the press. Brick to be regular in thickness must

all be of the same consistency or stiffness when they are placed in the press box, which is almost an impossibility; hence the advantage of the former system.

In the St. Louis, Mo., district the method of moulding is different from either of those which have been described. There no moulds are used. The clay is made very stiff and moulded in the press-box of a hand-press at the same time, and put out on the hot floor to dry without any immediate stiffening.

Concerning the method of making fire-brick, Mr. Thomas Pickering, of Chicago, Ill., recently wrote to Mr. Davis, as follows: "Having made fire-brick in England for eighteen years in the county of Durham and in Northumberland, near Newcastle-on-Tyne, it may be of interest to you to give the methods of fire-brick making in those two counties. I will confine my remarks simply to the making.

"The clay is on the moulding bench, and on the bench is a piece of flannel about twelve inches square tacked on the bench to make the ball on. There is a piece of wood two inches thick, five inches wide and ten inches long, covered with flannel stretched as tight as possible.

"The stamp is nailed on with a staple driven in at the end of a piece of wood, so that when the mould is put on, the stamp will be right in the center of the brick.

"The mould is solid brass with a flange on the top side of the mould, with no bottom. The mould is about ten pounds weight, with one side of the mould a little lower than the other, to allow for a little sagging when the brick is put down on edge. The mould is put on the piece of wood covered with flannel.

"Then the ball is made and thrown into the moulds, the surplus is taken off with the hand. Then a hardwood streaker is taken to smooth it off. The streak is then thrown into a little box filled with water in front of the moulder, which is called the streak-kit.

"The mould is emptied onto a pallet which is taken away by boys. Each moulder has two boys or girls. The moulder

must be careful to have the short side of the mould to the left hand, so that when the boy takes the brick up to put it on the floor the short side will be on the bottom.

"Circle brick and cupola brick are made the same way, and tiles weighing as much as twenty-five pounds. The moulds for cupola and special brick are made of wood lined with plate zinc.

"Some places all the special brick weighing over twelve pounds are made by the ton, paying from elevenpence to thirteenpence per ton. A moulder can earn from six to seven shillings per day, getting two shillings per thousand for brick. A moulder can make from 2,500 to 3,500 brick in a day."

Drying and Tempering. The paste made, and the article completed, it must be dried or "tempered." This for crucibles, retorts, etc., is commenced in the open air, and, if possible, out of the draft. If the draft cannot be excluded, the place where the drying takes place is slightly heated, commencing at a temperature from 60° to 70° F., and keeping it up from twenty-five to thirty days; then increasing it from 80° to 100°, leaving the article as long as possible, with an active ventilation, but the same temperature being kept up. The article should remain in a temperature of from 150° to 180° for at least six weeks. Brick, tile and blocks do not require so much care; but crucibles and retorts do. Long experience has proved that there is a great economy in conducting this process of tempering as slowly as possible, and that it influences materially the refractory nature of the article. It is found by actual experiment in crucible works that those crucibles made from the same mixture, tempered during six to eight months, last more than three times as long as those which had been tempered only two; so that, in general, the older the article before being burned the better. This desiccation, while perhaps it is the most important part of this manufacture, is undoubtedly the one most neglected. A poor article well tempered is often better than the best which has been hastily dried. By working rapidly and filling up cracks as they form in a

too-rapidly heated drying-house, with a very liquid material, in order to secure complete penetration, both time and money are lost. The material never lasts nearly so long as when slowly dried. In the works at Andenne, in Belgium, large pieces, like glass-house pots, are kept six months in the drying-house before they are used, and during this time the greatest care is taken to prevent drafts, so that no air colder than the drying-room shall strike them. Leaving the door of the drying-furnace open has been known to crack the pieces, which had been up to this point most carefully prepared and tempered.

The drying of fire-brick in the United States is done chiefly on fire-heated floors, but it is gratifying to note that floors heated by exhaust steam from the engine are at last coming to have their advantages recognized, as their construction and operation become better understood. These floors have been successfully used in England for many years. Both forms of dry-floors will be found fully described above. For large works there is no reason why the superior economy of tunnel-dryers should not be made available for drying the brick after being pressed.

The drying and tempering of all classes of refractory materials is an important part of the manufacture—the more carefully the drying of the clay-wares is conducted the more satisfactory and valuable will be the product. A poor article well tempered is often more satisfactory than a better grade of ware would be if too hastily dried. If there be no overheating of the brick on the dry-floor, there will result no cracking of them.

There should be no unnecessary handling of the green brick, and every precaution should be taken to avoid the chipping and other injuries which the brick have inflicted upon them before they are fired. The best way to obtain a high grade of fire-brick is to put them on a mildly warm floor and allow them to stiffen gradually through and through, so as to be in good condition for pressing the morning following the day during which they were moulded. After being pressed the brick can

then be placed on a hot floor and dried, care being exercised to let none but thoroughly dry brick go to the kiln. These precautions insure the production of sound and well-finished brick. In some fire-brick works the brick are taken from the moulder's bench and placed upon a floor which is much too hot, and from which in a few hours they are picked up and pressed and put down again to finish drying. The consequence of this method is that the brick are pressed before the middle of the brick is sufficiently dry—the outside and edges are hard enough, no doubt, for pressing, but the centres of the brick are much too soft for the application of pressure. Good fire-brick cannot be made after this mode. The custom is to keep the floors hot constantly; the mass of the body heated makes this easy to be done. The fuel used is coal slack in almost all cases, as its combustion is gradual, and after the floor is once hot, gradual heat is the kind wanted. Brick placed on such a floor dry in twenty-four hours from the tempered, plastic clay to a state so hard that the hand can make no impression on them. Lack of drying-floor constitutes one of the greatest obstacles to an increase of capacity of a factory. Air-drying is usually done in the second story over the ordinary drying-floor. If the roof be tight the heat in the second story is quite uniform, and is strong enough to do quite rapid work. The temperature is often 100° or 120° naturally, and by using a slat-work floor the capacity is largely increased. The kinds of ware adapted to air-drying are large pieces which the heat of a floor can only attack on one side at a time, which is always done at a risk of cracking.

In the manufacture of fire-brick on a large scale by the soft-mud process, when many thousand brick are moulded in a day, it is, of course, necessary to have some expeditious method of drying, and the rule in such works is to have the brick dry and in the kiln within twenty-four hours of the time when they were moulded. Although any suggestion that a longer time than this should be allowed the brick is scarcely practical, yet the fact cannot be controverted that the refractory qualities of all

classes of fire-clay wares are much improved by slow drying and long tempering in the dry-house. The various tunnel-dryers now on the market are well adapted to the drying of fire-brick in large quantities. After the brick have been made and dried they are wheeled into the kiln and set for burning.

Burning. The manner of setting the brick in the kilns depends upon so many circumstances that no general rule can be made for this part of the work. In kilns which are gas-fired the manner of setting is different from the way in which the brick are set for burning in coal-fired kilns. Special instructions on this point are always furnished by the builders of gas-fired kilns.

On the subject of setting and burning fire-brick and the construction and operation of fire-brick kilns a large volume could be written.

The Harbison & Walker Co., of Pittsburgh, Pa., use the Dunnachie gas-fired kiln, for which Charles T. Davis, of Washington, D. C., is the agent in the United States. For a description of the kiln see Chapter IX.

The most appropriate form of kiln suited to individual requirements must be determined by local circumstances, cost of fuel, labor, etc. Gas-fired kilns, however, are more economical to operate in both fuel and labor cost than are coal-fired kilns, and on these accounts are being adopted by the leading fire-brick manufacturers of this country and Europe.

Fire-brick require to be thoroughly burned, and if they possess any refractory qualities, a high temperature is necessary to accomplish this, in order to bring them to the point where the shrinkage or contraction shall have ceased. When taken out of the kilns, if not shipped away immediately, the brick should be stored in a good water-tight stock-shed, as brick and other refractory products should, if it is possible to avoid it, never be allowed to get wet.

In order to acquire and hold a desirable trade-demand for refractory materials, only first-class wares should be placed upon the market. In order to do this it is necessary to place

in charge of fire-brick works only experienced and careful fire-brick makers—men who will give their personal attention to all the details in the different processes of mixing the clays and the moulding and burning of the brick. The fire-brick having been made and burned, it is the duty of the manufacturer not to allow the brick to become exposed to the weather, and shipped away full of moisture, as it is expected that all fire-brick shall go to the furnaces for use, free from moisture.

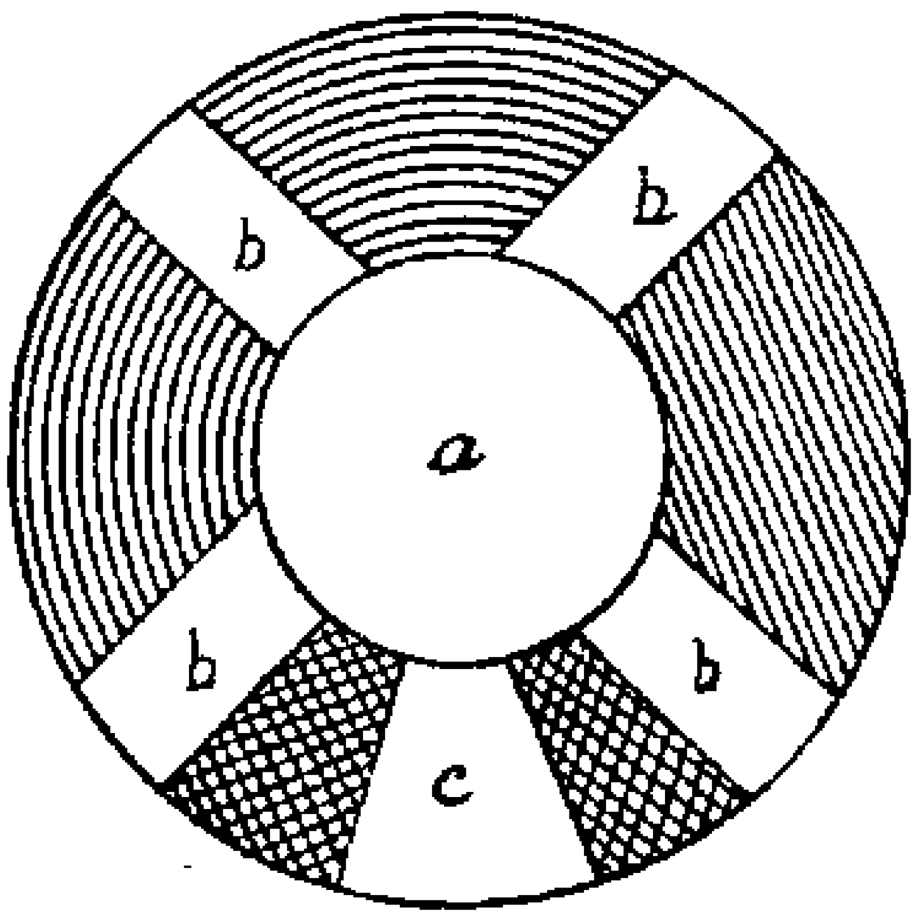
CALCINE KILN.

The quantity of "chamotte" or calcine required in a fire-brick works depends largely on the nature of the clay in use and the proportion of tiles and blocks made. If the supply of calcine required is of a limited character, lumps of raw clay may be placed in each kiln; but in cases where more calcine is necessary than this method will supply, it is advisable to make provision for the demand by the erection of a calcine kiln. This form of kiln is simple in construction, being erected somewhat after the plan of a lime-kiln, and worked in a similar manner; that is, the kiln is always kept filled. When the calcine at the bottom of the kiln is sufficiently burned, it is drawn out, the remainder settling down, leaving a vacancy at the top, which is filled with a further supply of lump clay, so that the calcining process is one of regular feeding and drawing out of the clay. In Figs. 127, 128 and 129 is shown a calcine kiln. The kiln is 5 feet in diameter, and 15 feet from the bottom to the cone or stack. The base has four fire-holes 18 inches wide, and fitted with 3-feet grates. Letters *d* and *c* represent the feeding and discharge doors, the clay being converted into calcine as it gradually descends from the height of the door *d* to the door *c*.

The calcine kiln should be built as near the mill-room as possible, and connected with the clay bank by a trestle at a line level with the feeding door *d*, so that the loaded cars may be run directly up to the door. Where there is no accommodation for thus conveying the clay to the calcine kiln, a hoist or

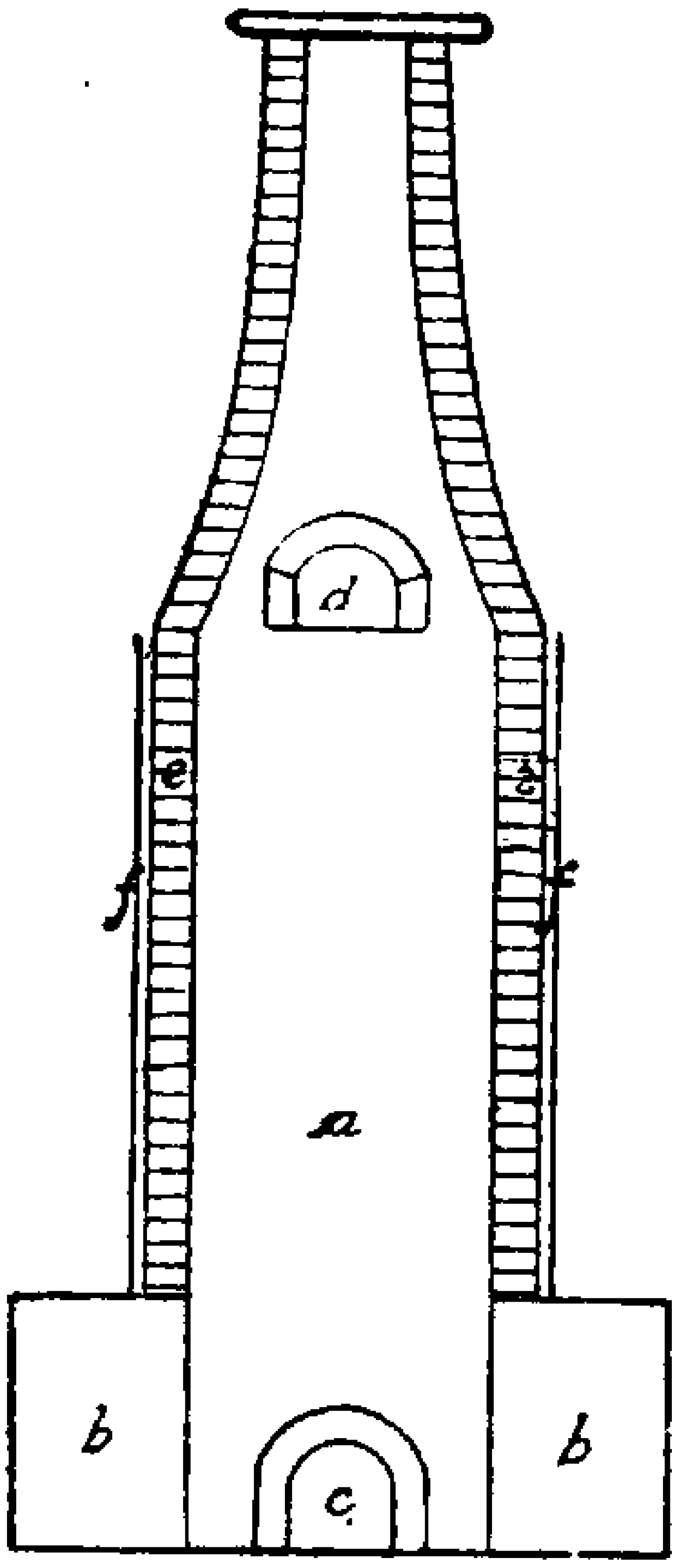
inclined plane would be necessary. The kiln being in close proximity to the machinery, this could be done at small expense.

FIG. 127.



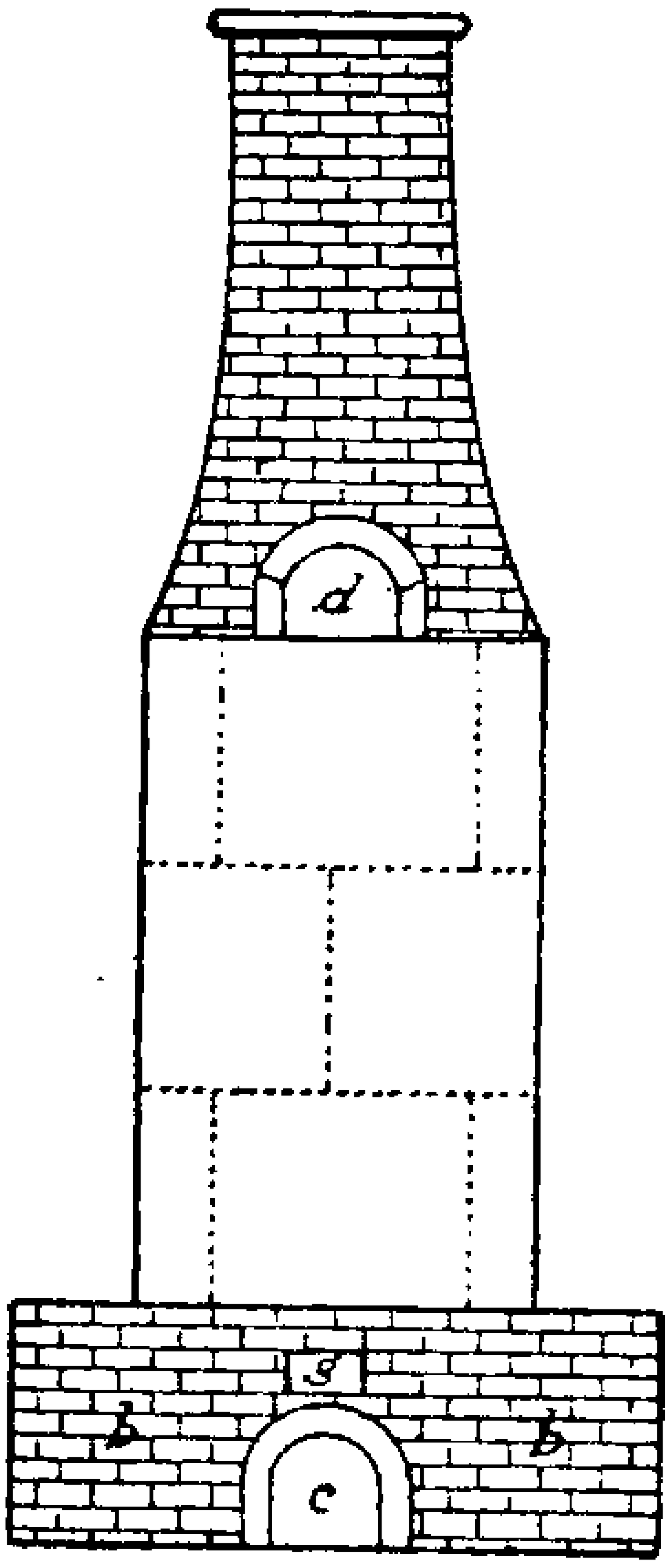
GROUND PLAN OF BASE, INCLUDING FIRE HOLES AND DISCHARGE.

FIG. 128.



SECTION THROUGH CENTER.

FIG. 129.



ELEVATION.

a—Area of kiln, 5 feet diameter, 15 feet to bottom or cone. *b*—Fire holes, 18 inches by 3 feet. *c*—Opening and door for discharge. *d*—Opening and door for feeding. *e*—Fire brick lining, 9 inches. *f*—Iron shell. *g*—Sight hole.

In order to secure a regular draft in burning the calcine, the clay should all be thrown into the kiln in lump form, fresh from

the mine, so that it is not air shaken and liable to break up when discharged from car to kiln, as the small clay would have a tendency to check the draft.

A calcine kiln of the size shown in illustrations would produce ten tons of good calcine each day. A smaller kiln with three fire-holes would work equally as well, of course yielding a less quantity of calcine.

SILICA FIRE-BRICK.

This class of refractory brick, also called "Dinas" fire-brick and British silica fire-brick, consists almost entirely of silica, and was invented by the late Mr. W. Weston Young, a land-surveyor, of Newton-Nottage, Glamorganshire, Wales.

The company first established to manufacture this kind of brick was organized by the inventor in the year 1822. The material at the "Dinas" (the well-known rock of that name in the Vale of Neath), from which Mr. Young procured it, is nearly pure silex; but from its lying on the limestone and occasionally intermixing with it, there is, taking the average of the general working, perhaps about five per cent. of calcareous matter and one per cent. of metallic, either iron or copper. The Dinas rock is believed to be the millstone grit of the Carboniferous System, and the geological equivalent of the bed, termed "ganister" at Sheffield, England, which is used as a lining for the Bessemer-converter, as well as for the manufacture of fire-brick now conducted in that locality.

The use of the "Dinas" was discovered about 1790, when the fine part of it was taken to one of the copper works and used as a cement, and for mending their furnaces while at work, by placing it with a long iron-handled ladle or spade where the wash of the metal had destroyed the brick; and, from its remarkable property of swelling in high heats, it fixed itself firmly. It gradually gained from one copper work to another till its use became general; in fact, they are not able to find any other sand that will answer the purpose so well. Its fire-proof qualities being known, many attempts were made to pro-

duce a brick from it; but all the common combinations of different clays, etc., failed.

When set in its own cement, for very high and long continued heats "Dinas" or silica brick will exceed in duration any other known brick. It does not suit every situation, as, in fact, no fire-brick will. The nature of it at once tells you it must not be placed near alkaline substances; neither will the effluvia from some lead-ores suit it. Perhaps it does not exceed Stourbridge brick for gates; but for the bodies of furnaces of most kinds it exceeds, as said before, that and every other known brick in duration. The manner in which the brick is made gives it a rough coat compared with most others; indeed it is peculiar in this respect. But, as it is made in machines perfectly square, all the managers of iron and steel works prefer it with a rough coat; they say it sets better in the work. This brick ought to be kept dry if possible, for being open in its texture, it imbibes moisture freely. The fire-place, roofs, sides, and bridge of the furnace, also the lower part of the stack, should be built of "Dinas;" the back part and the remainder of the stack will do best if built of No. 1 fire-brick, and the slabs for leaving the flues and doors are also best made of this material.

One of the troubles of clay brick, which silica brick escapes. is its so-called "dropping" when placed in the roof. This means either one of two things—first, that a crack has formed across the brick which leaves a piece free enough to fall when any change of temperature loosens it—this is the peculiar property of a pure clay; and second, the formation of a crust of fused clay and ashes on the surface which cracks off and falls when the brick cools.

In the construction of open-hearth steel and glass furnaces in the United States, silica brick have taken the place of the highest grades of fire-brick, and now that high grade silica brick of domestic manufacture are to be had, their use is rapidly extending to other furnaces.

All silica brick expand under the action of high heats. The

expansion of the best silica brick of American manufacture varies from one-eighth to three-sixteenths of an inch per foot according to the temperature carried in the furnaces in which they are used.

This expansion should be provided for in some manner in building furnaces, and this is done in various ways. Some users of silica brick merely loosen the tie-bolts of the furnace as it heats up. Others insert a thin board (say one-half inch) every four feet across the roof of the furnace, to allow for the longitudinal expansion, and the board burns out on the furnace heating up, the space being filled up by the expanding brick.

With circular furnaces, some arrange for the expansion of the roof, with a series of plates and sets-crews, which are loosened as the furnace heats up.

Arches over doors and openings may have an occasional shingle built into the joints to provide for expansion.

With straight walls a slip joint can be arranged that will close up when the furnace heats. Care should be taken, however, not to allow for more expansion than will actually take place, as otherwise there will be an open joint that may prove a weak point.

All users of silica brick should strictly observe the following rules:

1st. That the brick are kept perfectly dry.

2d. That in building, the brick are not laid too tight.

3d. That ample provision is made for the expansion of the brick as the heat is raised, without weakening the support of the furnace.

4th. That great care be taken in heating up the furnace to do it slowly.

5th. That the same material be used in laying the silica brick as that from which the brick are made.

6th. That when, for any reason, it becomes necessary to cool down the furnace, it be done as gradually and slowly as possible.

The appearance of the "Dinas" brick is peculiar in its color

and in the roughness of its surface. Silica brick should be regular in size, thoroughly burned, and the chemical analysis of brick made by the same manufacturer at different times should show perfect uniformity in quality, and these requirements only can be secured by the most intelligent and unceasing watchfulness in all the details which pertain to the production of this high grade of refractory material.

The way of manufacturing "Dinas" or silica brick for many years was a closely guarded secret, and it is only of recent date that there has been any certain knowledge of the mode of producing such brick.

The material, or, as it is locally named in Wales, "clay," of which silica brick is made, is found at several places in the Vale of Neath. It occurs in the state of rock and disintegrated like sand. Its color, when dry, is pale-gray. The rock, when not too hard, is crushed to coarse powder between iron rolls. By exposure to the air the hard rock becomes somewhat softer, but some of it is so hard that it cannot be profitably employed without the use of a Blake or other crusher. The composition of Dinas "clay," from two localities in the Vale of Neath, has been found to be as follows:

COMPOSITION OF DINAS "CLAY."

	I.	II.
Silica	98.31	96.73
Alumina	0.72	1.39
Protoxide of iron	0.18	0.48
Lime	0.22	0.10
Potash and soda	0.14	0.20
Water combined	0.35	0.50
	99.92	99.40

These analyses were made by Prof. W. Weston. No. I was rock of medium hardness, which was obtained near Point Neath Vaughan, and No. II was from the same locality, though not from the same mine. The powder of the rock is mixed and ground in a 9 foot wet-pan with about 1½ per cent. of lime,

and sufficient water to make it cohere slightly by pressure. A sober man should be employed to see that the ingredients used in giving the brick the bond are very evenly distributed in the pan, as this is one of the most important things to do in order to have the brick uniform in size. Good men should be employed at the pan, men who will see that every pan of the material is ground alike, as in no case should one pan be ground fine and the next pan ground coarse. Every pan of material should be ground alike, or the brick cannot be made uniform in size, as the expansion will be greater in some brick than others. The mixture of ground quartz and lime is pressed into iron moulds, of which two are fixed under one press, side by side. The mould, which is smaller than the brick is to be, is open at the top and bottom, like ordinary brick moulds, is closed below by a movable iron plate, and above by another plate of iron, which fits in like a piston, and is connected with a lever. The machine being adjusted, the coarse mixture is put into the moulds by a workman, whose hands are protected by stout gloves, as the sharp edges of the fragments would otherwise wound them. The moulds having been perfectly filled, the piston is then pressed down, after which the bottom plate of iron on which the brick is formed is lowered and taken away with the brick upon it, as it is not sufficiently solid to admit of being carried in the usual manner. The brick are dried on these plates upon hot floors warmed by flues passing underneath; and then they are pressed in hand presses and put on a floor made twice as hot as the floor they are moulded on, so they will dry very quickly. The Savage Fire Brick Co., Hyndman, Pa., uses with most satisfactory results several Raymond Power Represses made by C. W. Raymond & Co., Dayton, Ohio, for pressing silica fire-brick. When dry they are piled on end, usually in circular down-draft kilns, similar to kilns in which ordinary fire-brick are burned. The brick must be set in one kiln properly. Every head or bench should be perfectly level, so that the brick can settle evenly, and the setter should be very careful to allow

enough room for expansion. About 8 days' hard firing are required for these brick, and about the same time for the cooling of the kiln. The cooling can not be hastened without detriment to the brick. One kiln containing 50,000 brick consumes 65 tons of coal, half free-burning, and half binding. The heat required to burn a silica brick is so high as to burn a second-grade fire-brick to a running mass. In the burning of silica brick the heat has to be equal to the highest grade of fire-brick and has to be held fully twenty-four hours longer than for the highest grade of fire-brick made from the non-plastic or flint fire-clays. Silica brick are manufactured of various shapes and sizes, to suit the furnace builder.

The fractured surface of these brick is uneven, showing coarse irregular white particles of quartz, surrounded by a small quantity of light-brownish yellow matter. The lime which is added exerts a fluxing action on the surface of the fragments of quartz, and so causes them to stick together. From their silicious nature it is obvious that silica brick should not be exposed to the action of slags rich in metallic oxides.

So scrupulous are the managers of some works producing silica brick that they cause the silica to be weighed after coming from the Blake crusher and before being put in the wet-pan; the same care being exercised in determining the quantity of lime admitted into the wet-pan with the charge of silica to be ground. Other manufacturers of silica brick do not weigh the constituent materials, but judge the proper mixture by the consistency of the lime liquid and by the stiffness of the ground mass. The silica material is ground and mixed in all respects the same as for ordinary fire-brick. The greatest watchfulness is required to be observed in the preparation of the lime liquid which forms the bond or binding material which unites the silica. The quantity of lime contained in the mixture must not be excessive—it should not exceed two per cent. of the entire body in the best grade of silica brick. The knowledge of the manner in which the binding material is prepared so as to obtain the best possible results from the smallest quantity of lime

is one of the principal points where the practical experience of men trained in the business of silica brick manufacture is of great value.

The lime used as a binding material in the manufacture of silica brick is dissolved in a board box similar to that used by plasterers, and from this box the lime is run in a thin state into the settling vat. From this settling vat the lime is gently decanted into the third vat or barrel, care being observed that none of the thick sediment from the lime is taken up from the bottom of the settling vat. It is necessary that the lime should be as nearly pure as it is possible to get it, as also the carbonate of lime which is in part used. In the third vat or barrel there is placed a spiral agitator which lifts the material always from the bottom of the vat or barrel, thereby keeping the lime of a uniform consistency and preventing the heavier particles of lime from settling to the bottom of the vat or barrel from which the lime solution is run by means of a small pipe into the wet-pan, to be there incorporated with the silica which is being prepared for the moulders.

There are several firms in the United States at present engaged in the manufacture of silica brick, among which are Harbison & Walker Co., Pittsburgh, Pa.; The Savage Fire-Brick Co., Hyndman, Pa.; Reese, Hammond & Co., Bolivar, Pa.; A. J. Haws & Son, Johnstown, Pa. A large part of the quartz used by the manufacturers of silica brick in the State of Pennsylvania is quarried in Wills Mountain, Pa.

Great care should be used in selecting the silica quartz; and in order to do so, good reliable men should be employed in the quarry, men who are acquainted with the quartz, as this is most important.

The silica brick now made in the United States by the leading manufacturers will equal in quality the imported Dinas material.

The following is the result of an analysis of one of the "Star Silica" brick:

CARNEGIE, PHIPPS & CO., LIMITED,
PITTSBURGH, Feb. 16, 1891.

MESSRS. HARBISON & WALKER, Pittsburgh.

Gentlemen:—The report below gives the analysis made at our Homestead Works, of Silica Brick of your manufacture:

"STAR."

Silica	96.02
Alumina	1.13
Peroxide of Iron	0.72
Lime	2.10
Magnesia	0.02

Yours very truly,
OTIS H. CHILDS, Sec'y.

Consumers of silica brick not infrequently complain that the analyses given by manufacturers of silica brick are very different from the results obtained by them, when they analyze the brick received, and hence if a manufacturer intends to maintain the standard desired for his brands of silica brick he must be ever watchful and cautious in all that pertains to the details of their production.

One of the principal items of cost in the manufacture of silica brick is the expense for fuel, and when the burning is done with solid fuel, such as coal, the labor of handling the large quantities of coal and resulting ashes is also very costly.

In order to lessen the fuel and labor-costs of burning silica brick The Gleboing Union Fire-Clay Co., Limited, of Glasgow, Scotland, and Messrs. J. Grayson, Lowood & Co., of Sheffield, England, as well as a large number of other silica brick manufacturers in Europe and the Harbison & Walker Co., of Pittsburgh, Pa. have adopted the Dunnachie continuous regenerative gas kiln, which gives a better and more uniform brick than can be obtained by direct firing. The brick made by Messrs. J. Grayson, Lowood & Co., are made from the material locally termed "ganister" and are principally employed for lining the Siemens-Martin furnaces and other fire-places exposed to a high degree of heat. According to G. J. Snelus, the composition of these brick is as follows: Silica, 95.4 per cent., alumina, 3.10 per cent., and lime, 1.68 per cent.

The brick, it is claimed, have the advantage of not expanding at a high temperature.

CARBON FIRE-BRICK FOR FURNACES.

For the preparation of these brick, coke is ground and sifted and intimately mixed with about twenty per cent. of tar, the mixing being under certain conditions effected in a somewhat warm state. The extraordinarily plastic mass is then stamped in thin layers into sheet-iron boxes, which can be closed with hinge-joints, care being had in filling in new mass to always scratch up the surface. The brick cannot be taken from the mould, but remain in it for drying, which requires about fourteen days. The manufacture scarcely differs from that of ordinary fire-brick. In burning the brick the air has, however, to be entirely excluded; even the interspaces in the muffles are filled up with coke dust. By heating, the brick become first soft and try to expand, which, however, is prevented by the coke dust.

The manufacturers usually use for the purpose muffles of crude clay which burn to chamotte. It is unnecessary to remark that everything must be thoroughly luted to prevent the access of air. By burning the tar carbonizes and forms a solid mass with the particles of coke. Hence the manufacture of these brick, whether large or small, presents no especial difficulties.

As long as the Enskirchen steam brickyard at Mechernich had the monopoly of the manufacture of these brick in Germany, the forms prescribed there had, of course, to be accepted. However, this is now changed, and well-shaped brick 20 to 32 inches long, 20 inches thick, and 7¾ inches wide are now manufactured.

The price of these brick is at present twice that of ordinary refractory brick for furnaces. They are, however, specifically much lighter, the weight per one cubic yard being about 2640 pounds, whilst at least 4400 pounds must be calculated for fire-brick.

Carbon brick were at first only used for hearth blocks and the hearth up to the tuyeres, but at present the boshes are also built of these brick, which must be considered an advance of great importance since the danger of the charge remaining suspended can thereby be avoided.

Great practical difficulties were encountered in placing the brick in position. After being rubbed smoothly upon each other, they had to be warmed and the tar, which served as mortar, applied warm. The workmen suffered much from the tar vapors, ulcers and boils being formed on the hands and eyes. This mode of setting the brick is now, however, done away with, a mortar four parts coke powder and one part fine red clay being at present used.

GLASS POTS.

The practical success of the "tank system" of glass manufacture has not as yet curtailed the demand for glass melting pots. These pots are composed of clay, which is required to be as free as possible from lime and iron. A clay obtained from the carboniferous shales of Worcestershire, in the neighborhood of Stourbridge, England, is highly esteemed for the manufacture of glass pots. There are also several American and German clays which are suitable for the purpose of producing the large pots in which glass is melted and worked.

These clays are, 1st, Gross Almerode, near Coblentz, Germany, for bond clay; 2d, Christy clay, from near St Louis, Mo., used for calcine and bond; 3d, Blue Ridge, Missouri, clay, used for bond and calcine; 4th, Mineral Point, Ohio, flint clay, used as flint and calcine; 5th, old pot shells for calcine.

The German clay is shipped as ballast in the holds of vessels, and hence transportation costs but little. It is an excessively fine-grained and heavy clay, and is very plastic, making a better bond than any native clay. It comes in blocks 9x6x6 inches, which have to be pared with a draw-knife, and then broken and inspected and all irony spots removed. No

pieces larger than a walnut are allowed to go into the mixture. The work involved in getting the clay ready for use is excessive, and it is the opinion of those at the works that it is much overrated. It is an excellent bond clay, it is true, but its refractory properties are excelled by the Christy clay of Missouri.

These Missouri clays come in blocks, either calcined or raw. They are pared and broken, but not sorted over. They are washed before shipping, so that they are much finer than in nature. The Blue Ridge is the finer-grained of the two. The Mineral Point calcined clay is not now largely used, because the old pot-shells, being already in the desired composition of the mixture, make a better calcine than any single clay.

These shells are chipped with small hammers until no part of the surface remains and only the clean interior is left. The charge is composed quite largely of calcine with a little flint clay, and the remainder German and Missouri bond clays. The mixture is ground in a dry pan and sifted in a jig bolt, and the coarse part re-ground. It is then pugged five or six times in succession, and then is stored and blanketed. It remains in this state until it sours and smells offensively, which the men claim is necessary to its proper working. It is wedged by hand and is ready for use.

When required for forming the pots, a sufficient quantity of of the clay is taken and kneaded with one-fourth of its quantity of the material of old pots, which are ground to fine powder and carefully sifted: this material gives firmness and consistency to the paste, and renders it less liable to be affected by the heat. The pots are of two kinds, the open and the covered. The first are used for melting common glass, such as window and bottle glass; the other for flint glass. In each case, the pots are made entirely by hand, and require great skill and care.

The pots are large structures about five feet high, four feet wide, and four feet long, bounded on top and side by covered walls, and on the bottom by a flat face. They weigh from 2,000 to 3,000 pounds, and sometimes as much as 3,500 pounds. They are made from three to five inches thick with a

thicker floor, and are each built on a small platform covered with gravel, so that the air may circulate beneath them and dry them faster.

The flint glass pots are only from two to three inches thick. Each builder has on hand twelve or fifteen pots at once, on which he daily builds a little more, until at the end of three weeks or a month he finishes them all together. The buildings in which glass pots are made are provided with elevators so that the heavy pots can be handled without danger of injuring them.

When the bottom is finished, the workman begins to build up the side of the pot by first forming a ring of the same height all round, taking care to round off the upper edge to a semicircular curve of great regularity; upon this he begins bending over other lumps of the paste until another equal layer is formed, and these are continued until the pot is complete; the workmen spread wet clothes over the edges when they discontinue working. This is necessary, to admit of a certain amount of drying, otherwise the large weight of clay used would prevent the form being kept, and the pot would either fall to pieces or lose shape; the building of the pot is consequently extended over several days. After the potter has finished his work, the pots are removed into the first drying floor, where they are only protected from draughts, so that the drying may be conducted with the greatest possible uniformity. When they have progressed sufficiently, they are removed to the second drying floor, which is heated with a stove, and the drying is here completed. They are then placed in the store, where usually a good stock is kept on hand, as time improves them, and they are seldom kept less than six or nine months.

The pots are shipped on three-wheeled trucks, which are returned to the works, so that they are loaded and unloaded with ease and security, where before there was always great danger of breaking down. The work must be under most intelligent supervision.

When required for use, the pots are placed for four or five

days in the annealing furnace, which is on the reverberatory principle, and they are there kept at a red heat. This furnace is so situated, that the pots, when ready, can be very quickly transferred to the main furnace—an operation of exceeding difficulty, and requiring great skill and dexterity, as they have to be removed whilst red hot, and it must be done so quickly that no sudden cooling shall injure the pot, a difficulty which can only be understood by remembering that the ordinary pots are nearly four feet in depth, are the same in width at the mouth by about thirty inches at the bottom, and they weigh several hundred-weight. The enormous amount of labor bestowed upon these pots makes them very expensive. Their removal from the annealing-oven to the main furnace is effected by an immense pair of forceps several feet in length, which are placed horizontally upon an upright iron pillar about three feet in height, which rises from a small iron truck on four wheels, so that the whole apparatus can be easily moved from place to place. By means of this instrument the pot is lifted and dexterously withdrawn from the oven, and as quickly transferred to its position in the main furnace, in which usually 10 or 12 are placed on a platform of fire-brick or stone, each pot being opposite to a small arched opening through which it can be filled and emptied. The entrance to the main furnace, through which the pots have been introduced, is then closed, with a movable door of fire-brick, and covered over with fire-clay, to prevent the escape of the heat.

The material used in the construction of the arches, as well as walls of large glass ovens, is best produced from the Stourbridge or similar clay, which is carefully shaped into large slabs, and faithfully dried for more than a year; but it is not burned in the kiln.

Some of the leading manufacturies of fire-brick keep on hand various sizes of jack brick, and are also prepared to make any special shape of jack or glass pot stopper that may be wanted, and keep them on hand for any customer using them regularly. For the crowns of furnaces, brick are made to any pattern that

may be desired—but usually twelve inches long, with the lines tapering to suit the radial lines of the furnace. For those glass manufactures who have mills and are prepared to manufacture their own shapes, the fire-brick manufacturers keep a large stock of different clays on hand, calcined and green. The calcined clay should be all carefully selected and thoroughly burned.

For building the eyes of furnaces, repairing benches and making flue-brick, etc., fire-brick manufacturers carry a stock of batch clay which should be prepared very stiff so as to require thorough ramming in order to get it securely in its place; and the same stock when desired can be made into blocks to form the eye, and burned.

GAS RETORTS.

Fire-clay gas retorts have almost entirely replaced the old form of iron retorts, as they possess when properly made the excellent advantage of neither expanding nor contracting upon being heated and cooled.

In Figs. 130 to 135 are illustrated the various forms of gas retorts in common use.

The manufacture of clay retorts for making gas is now carried on largely.

The clay body is compounded to stand considerable heat without any tendency to soften, for so large a piece of hollow ware must be refractory to maintain even its own weight at the temperature used. The mixture requires more care in compounding than a brick mixture, for more is involved in the failure of a retort to do good service than a few brick. Calcine is used in large amount, but crushed rather finer than common, and it needs a very good and plastic bond clay.

The retort is shaped from the tempered clay by filling the space between a large sheet-iron shell and a wooden core. The shell is placed in position and the floor covered with clay four inches deep and tamped. The core is then introduced and adjusted so that four inches separate it from the walls on all

sides. The clay is filled in small amounts at a time and tamped gently. When the retort is high enough, the core is withdrawn by a crane and the mouth of the retort built by

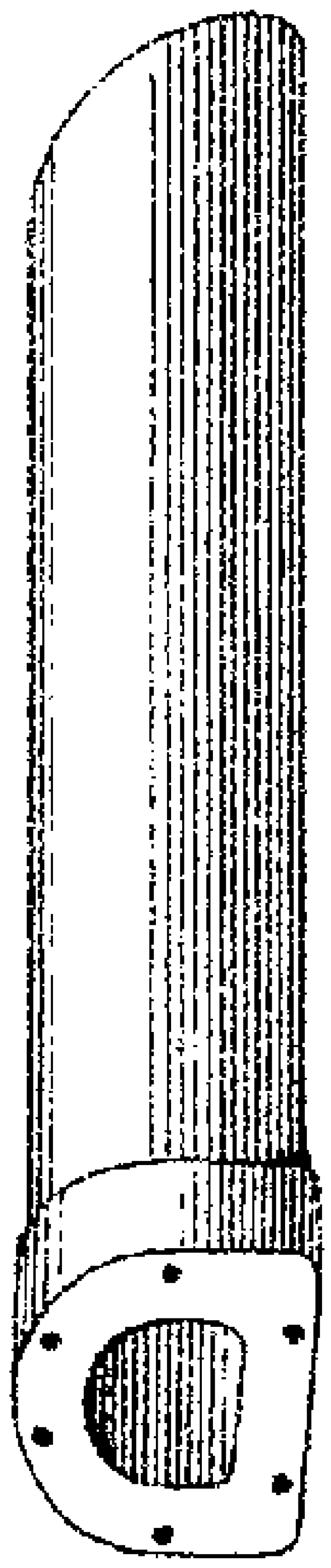


FIG. 130.

▢ Shaped Retort.

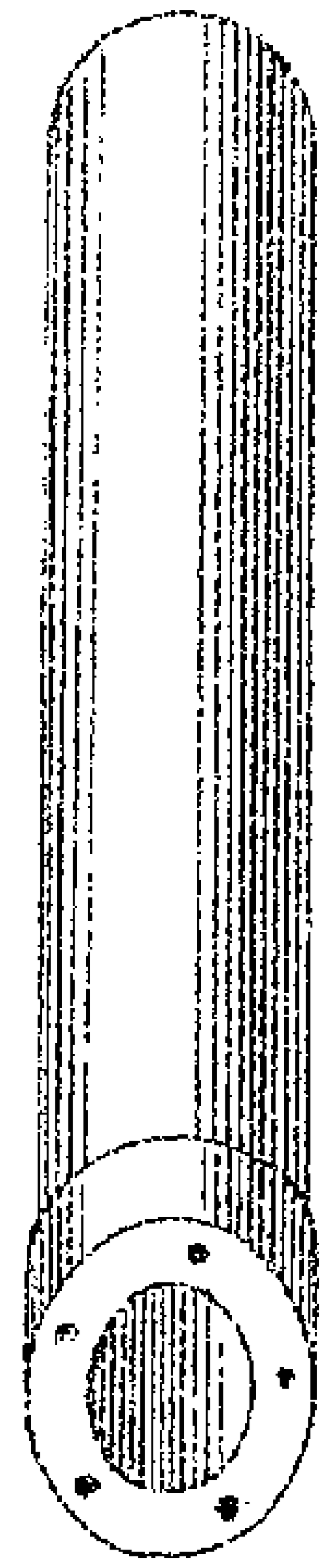


FIG. 131.

Oval Retort.

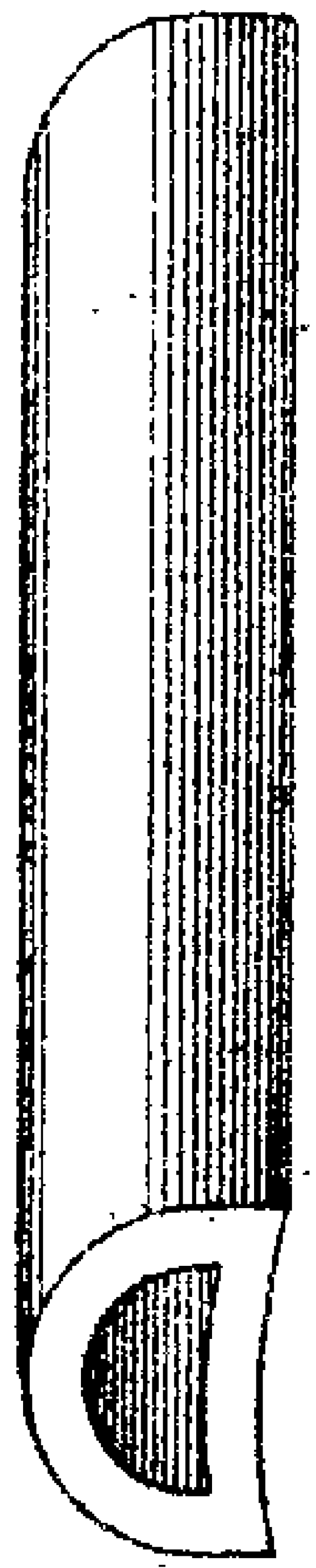


FIG. 132.

D Shaped Retort

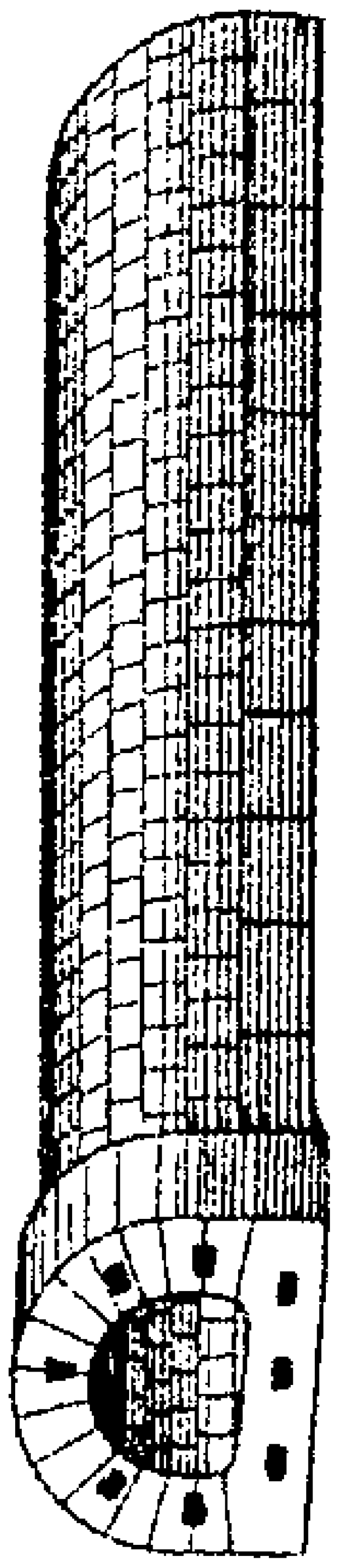


FIG. 133.

Brick Built Retort

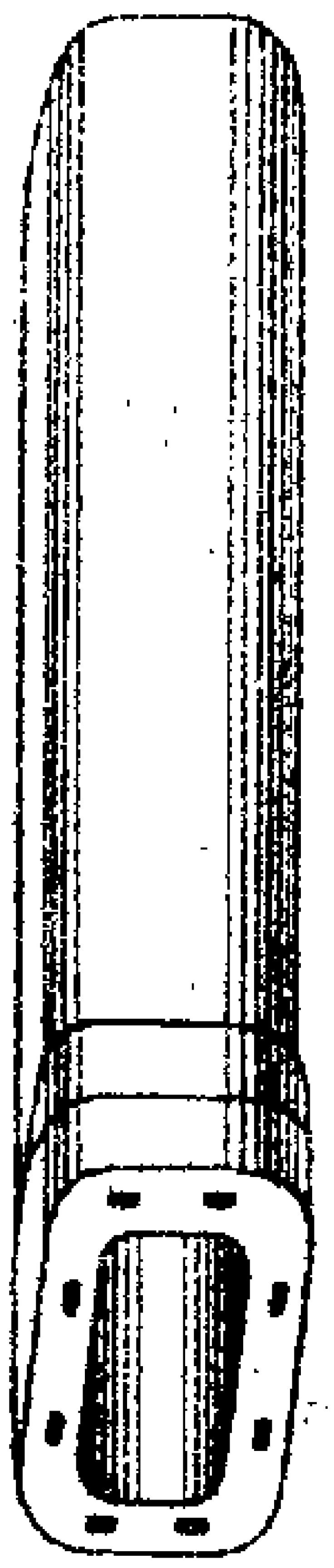


FIG. 134.

Square Shaped Retort

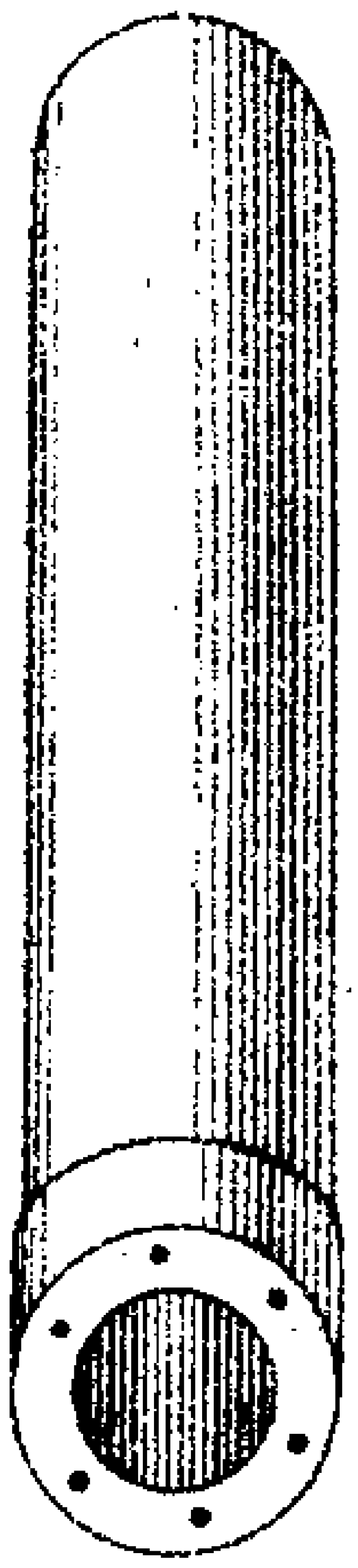


FIG. 135.

Round Retort

hand. The shell is then unbolted and removed in two pieces, and the finished retort is standing on its end. It is left to dry for several weeks in this position, and is finally removed to the

kiln to be burnt. It is put into an ordinary fire-brick kiln and brick are piled around it to keep it in position without sagging, and when in steady use, and never allowed to cool, they prove very durable.

WEIGHTS AND SIZES OF GAS RETORTS.

Retorts are built to sizes and shapes as ordered, and to fit any mouthpiece. The more usual sizes are:

D Shape.	Probable Weight of Retort 9 feet long.	Round Shape.	Probable Weight of Retort 9 feet long.	Oval Shape.	Probable Weight of Retort 9 feet long.
18 in. × 13 in. inside,	14 cwts.	13 in. inside,	12 cwts.	18 in. × 14 in. inside,	14 cwts.
20 " × 13 " "	15 "	14 " "	13 "	20 " × 14 " "	15 "
21 " × 15 " "	16 "	15 " "	14 "	22 " × 14 " "	16 "
24 " × 14 " "	17 "	16 " "	15 "	24 " × 14 " "	17 "

CHAPTER XI.

THE MANUFACTURE OF ENAMELED BRICK.*

GENERAL REMARKS.

THE art of enameling brick is older than recorded history. It was practiced in Assyria, Babylonia and Chaldea. The Moors brought the art with them from the East when they extended their domain into Spain and over Western Europe. The Moors derived their knowledge from India, and primarily from China. With the decline of the Moorish civilization the art of manufacturing enamel brick and tiles was lost to the Western world, still being retained, however, in the Orient.

The great surviving monument of Moorish art in brick and tile enameling is the interior decorations of the walls of the Alhambra Palace at Granada, in Spain. For over a thousand years knowledge of the art of brick and tile enameling slumbered in Europe, and was only revived when the Crusaders from France visited Byzantium, Palestine and Syria, and when returning carried to France knowledge of enamels and also workmen skilled in their application to clay bodies. From France — especially from Normandy — the art of making enameled brick and tiles spread through continental Europe and to England.

With the vanishing civilization of mediaeval times this art was again lost to Europe. It has only been during the past forty years that the manufacture of enameled brick has again been put upon a successful basis in England, and only during the past twenty years that it can be said to have become financially profitable.

*A lecture delivered by Charles T. Davis at the annual meeting of the National Association of Fire Brick Manufacturers held in New York City, December 2nd and 3rd, 1891.

The problem which now confronts us is "Why can we not manufacture enameled brick which will compete with those of England in both quality and price?"

There is only one answer to this question—we lack specific knowledge regarding the details of the subject.

Diodorus Siculus relates that the brick of the walls of Babylon, erected under the orders of Semiramis, were decorated with all kinds of living creatures portrayed in various colors upon the brick *before they were burned.*

In spite of this positive information concerning the way in which the enamel decorations were applied to the brick which formed the facings of the walls of Babylon, nearly all persons who, forty years ago, endeavored to manufacture enamel brick, thought that it was necessary to enamel the brick only *after* they had been once burned. The loss of time, the injuries which resulted to the brick, and the great cost incurred in first burning the brick, then enameling them, and then burning the brick the second time, forced the manufacturers of this class of goods to abandon such wasteful methods, and to apply the enamel to the brick in the green state and complete the burning process in one operation. A brick which has once been burned and afterwards enameled and again burned does not make as good a product as is had by the one-burning process, as the enamel being applied to the dry surfaces does not adhere firmly, and commonly scales completely off after the brick are laid in the wall. The enameling as well as the burning of the brick must, however, all be done in one firing, and if done otherwise the results will be neither satisfactory nor profitable.

It will readily be seen from the foregoing remarks that easily-fused enamels, such as those containing lead, cannot be employed, as such enamels would be destroyed in the heat of the kiln and pass out with the gases long before the brick themselves were burned, especially as the brick used for enameling are made from fire-clay.

Hence it is of primary importance for enamel to coincide with the contraction and expansion of the clay body to which

it is applied. It is also necessary that enamels should not be fusible at any special temperature, as the fusing point of enamels must vary according to the degree of heat which the clay body upon which they are placed will stand. The constituents, therefore, which form the enamel must be of such a character that their mixture will withstand high temperatures without danger or injury, and the brick to which the enamel is applied must be sufficiently refractory so as not to melt or get out of shape during the time when the enamel is being attached to it in the firing process.

Manufacturers of enamel brick in England do not allow their employes to become conversant with all the details which relate to the production of this class of wares. A man, boy or girl once employed in any enamel brick works in the old country is assigned to some special department of the factory, and remains employed in that same department so long as he or she may be an employe. In this way it is quite impossible for the employes in an enamel brick works to acquire a thorough knowlege of the the business in all its various ramifications. Should an employe of one enamel brick manufacturer leave his place and seek employment with some other manufacturer of enamel brick in the same neighborhood with a view of extending his knowledge of the business, he is foiled by the surveillance which the various manufacturers maintain. The person seeking employment is asked upon which special branch of work he was last employed, and is assigned to that department, if employment be given him. If the person seeking employment states that he was employed in some branch other than that in which he was employed, the fact is soon discovered by lack of familiarity and skill, and hence such persons are at once discharged, and it becomes a matter of impossibility for such a person to again find employment in that particular section of England. In this way the manufacturers of enamel brick are protected, and their employes develop a high degree of skill and become experts in their various departments of work. But this special knowledge never becomes general knowledge, and hence no matter how

expert a man may become in making, pressing, dipping, setting, burning or sorting enamel brick, there is no possibility for him, under the English system, to become thoroughly skilled in all the departments of enamel brick manufacture. Large sums of money have been lost in the United States by brick manufacturers who do not understand these facts. They naturally thought that if a man was an expert burner, or an expert in any other department of enamel brick manufacture, that he was an expert in all the departments. The failures which have resulted from such false starts have done much in the past to retard in this country the successful development of the art of enamel brick manufacture.

One great point in which manufacturers of enameled brick in the United States will be for a long time deficient, is in not being able to secure skilled labor in all the various departments, as is always possible now in England.

Manufacturers who desire to make a success in the production of enamel brick must study the subject thoroughly so as to understand fully all the details which pertain to the entire process, and in addition experienced persons must be placed in each of the various departments of the work.

In experimenting with the various enamels, the preparation of which the writer will give later, do not be discouraged if you do not achieve satisfactory results in the first trials. From 50 to 100 brick for experimenting purposes should be made at one time. In this way the costs of the experiments will not be great, and by repeating the experiments several times better knowledge of the business will gradually be gained, and this is the only way in which manufacturers can secure desired results.

No matter how great may be a man's knowledge of brick enameling, no matter how great his practical skill, there is probably not living any person who can locate himself in any brick works and there successfully manufacture enamel brick of salable quality the first time he makes the effort to do so. But there are no obstacles pertaining to the production of this class of wares which cannot be eventually overcome by the man who

possesses the necessary knowledge and skill. There may be special drawbacks with the clay from which the brick are made. The clay may contain an excess of silica, in which case the brick would increase in size on the application of high heats, and would contract on cooling, thus destroying the enamel surfaces. There may be other difficulties in the way of successful results; but no matter what these difficulties are, a man who thoroughly understands the business should produce in his second or third kiln enamel brick of salable quality. If he does not accomplish this, there is but little hope of achieving successful results with that particular man in charge. One glaze and enamel, and the same method of procedure, will not suit all clays and all places. The enamel must be made to suit the clay—if the clay is very refractory the enamel must also be hard to fuse, for it must not flux when the brick is only half burned.

The brick and the enamel must both shrink in the same degree, for if the brick has a greater shrinkage than that of the enamel, the latter will fall off; and if the enamel has a greater degree shrinkage than the clay body to which it is attached, the enamel will crack crosswise.

THE CLAY.

The best clay for the manufacture of enameled brick is a high-grade fire clay, light-buff in color and plastic when ground, one which is practically free from iron, and which will vitrify at a medium-high temperature, and have a shrinkage of not more than three-quarters of an inch to the foot.

PREPARING THE CLAY.

If possible the fire-clay should be weathered—the longer the exposure the better will be the brick.

The dry-pan and riddel and wet-mixing pan will temper the clay finely and evenly and impart to it a more desirable consistency than will any other method of preparing the clay.

MAKING.

Any good wire-cut brick machine can be used for making the brick, provided only water from the lubricating die is allowed to come in contact with the clay while it is being moulded.

In England nearly all brick which are to be enameled are made by hand.

It is of great importance that the size of the mould should be such that when a proper allowance has been made for shrinkage, the brick, when placed in the press box, shall fill it as uniformly as possible, and of just right proportions to enter the box cleanly.

In employing machinery, care must be exercised in order that none of the oil used for lubricating the cutting table or rollers, or any other portion of the mechanism where oil is commonly used, is communicated to the green brick. Brick containing oil cannot be successfully enameled, and all brick which contain grease of any character must first have such grease removed from their surfaces before they are dipped.

Paraffine and olive oil are the best lubricants to be used on all machinery to be employed for the making or pressing of brick which are to be enameled. Such lubricant oils as are generally used for brickmaking machinery must, under no circumstances, be employed. It is desirable that a lubricating die, whose only lubricant is water, should be employed with stiff clay machines used for the making of the brick. The brick should be made stiff enough so that when they come from the cutting table they can be hacked on the hot floor seven or eight courses high, and they should be allowed to so stand without any further handling until the steam has been dried out of them. One great trouble with brick made by machinery is that sufficient attention is not paid to the adjustment of the die of the machine. The die must be a little smaller than the mold-box of the press, otherwise the brick require dumping to make them pass free and clean into the press box. Another trouble with machine-made brick is that

sufficient care is not exercised to keep them free from finger and thumb marks, and from other defects which materially lessen the value of the finished product. When machinery is under the management of careful and intelligent men, there is no reason why the machine-made brick should not fully equal those made by hand. If made by hand an experienced moulder must be assigned to the work and brass molds only should be employed; no sand must ever be used—only water to make the brick slip clean from the mold—the molds being dipped in the water-tub after every two brick are made.

The brick are made on a hot-floor the same as other fire-brick. The floor upon which the brick are placed to harden must be only warm, not hot, and the off-bearer must put the brick on the floor very carefully, in order not to destroy their perfect shape. Iron plates, however, are apt to oxidize, and this oxidation becoming incorporated in a minute quantity with the edge of the brick lying on the plates, has a tendency to discolor the body and glaze, causing the brick to look very unsightly. The flat sides of the brick are usually depressed—the name of the firm manufacturing the brick being in one depression and the initials in the other. This gives the mortar a better hold and also makes the brick easier to burn.

THE FLOOR.

The heating of a brick-making floor is one of great importance, and requires most careful consideration as to its construction. How many floors have been laid on most costly systems, only to be removed as unsatisfactory, or have required endless repairs to keep them in order, and in case of steam heating to keep them steam tight. The exhaust steam from the engine may be satisfactorily utilized to heat a very large area. It is the best medium, giving more uniform heat than when the best system of flues is used; it is much more cleanly, and is cheap. Where, however, "live" steam from the boilers must be used, requiring additional boiler and plant, the saving is not so much as is popularly supposed, and excepting under a strong and

undivided management, it is difficult to insure a good supply being maintained during the night.

The following is a good and well-tested system in present use. To prepare the ground take out all old flues, etc., if any, to the depth required, about two feet; well ram the soil or clay for a foundation perfectly solid and level; then lay 6 in. to 9 in. bed of concrete, rough towards the bottom and finer towards the face; and finally finish with a thin layer of good cement or lias lime. If cement is used of a high-class quality, it may be mixed with a proportion of sand to reduce the cost; but the object of this face is to prevent the steam and hot water percolating through the concrete, and causing loss of heat, etc. The bed of concrete must be laid with a small fall towards the drain on the side furthest from the steam supply; the drain will also have a fair amount of fall towards a central well and discharge pipe. There should be provided a steam trap, to check the too ready escape of the steam.

Now, if the size of the quarries to be used for the first course is 24 in. by 24 in. by 2½ in. or 3 in. thick, at distances of 19½ in. apart, three courses of brickwork must be laid in open chequer work, leaving about six inches clear at the steam supply end. Upon these courses of brickwork the first course of quarries is laid, resting 2¼ in. each end on the brickwork. On top of these lay a second course of quarries, forming the floor surface, bedded in pure cement. The work must be done with the greatest care to ensure a steam-tight and damp-proof floor when laid, all joints must be grouted with cement until quite full. The top course of quarries must be arranged so that they break joint with the lower course in both directions; in no case must the joints be allowed to fall upon one another. The top course of quarries need not be more than 2 in. thick; they must be thick enough, however, to insure their being level and straight, and it will be found necessary to use two sizes, probably, to ensure a uniform crossing of the joints.

It is of great importance that the floor surface is level and free from hollows at the joints or curved quarries, as it has been

found by long experience that a twist given to a brick by being laid on an uneven floor is never totally eliminated by pressing, etc., and still exists in the finished brick. It is therefore advisable, when possible, to have the floor quarries of such a size that a certain number of brick lie on each without crossing the joints; thus 8 brick can be laid on a 24 in. by 24 in. quarry. The steam supply is distributed evenly by cast-iron pipes, about 2½ in. diameter, having holes drilled in them on one side, one of which is central between each of the rows of chequered brickwork. This is supplied with steam from pipes carried overhead from the boilers into the sheds, and then brought down to the floor by a vertical pipe; 3 in. diameter will be quite large enough for any section, as large as it is desirable that they should be. Each supply pipe is provided with a valve to regulate the admission of steam, or when necessary to cut out the section from use.

It is desirable and usual to lay a floor of this description in sections of from thirty to fifty feet in length, each section having its own supply pipe and valve and steam trap at either end, so that if the whole be not required, a portion may be shut off, economizing steam and fuel, and also rendering them easier of repair. This obviates throwing a large part of the floor idle, and allows each section to be graduated in heat as may be required, so that too large a quantity of brick are not ready for getting up at once, thus causing waste.

Brick laid on a floor of this class in regular working are ready for taking up in about twelve hours from the time they have been made during the day; but the more slender the clay and the closer, the longer must be the time allowed for drying. It is often necessary to allow them forty-eight hours in which to stiffen. Another plan, instead of the concrete foundation—cheaper, and having much to recommend it at works where there is only too often a large number of wasted, unsalable brick, but not so efficient in preventing the percolation of water—is to lay a course of brick, fire or old glazed, which must be fairly well burnt, on their edge on the bed of well

rammed clay. They must then be carefully grouted with any suitable material, and after the brickwork courses are laid, filled in between with a thin layer of cement. This system is also in very successful use. At all places where a steam floor comes up to the main walls, or divisional walls of buildings, the building must be faced with cement, or the steam and moisture will rise, rotting the brickwork, and making the shed damp and look very unsightly.

PRESSING.

When the brick have remained on the floor a sufficiently long time to allow them to become hard enough to handle without marking them, they should be carefully taken from off the floor and placed in a cool location and covered over with canvas or sacking and allowed to "sammy," or in other words to come to an even state of stiffness, which will require about ten or twelve hours.

The brick can be pressed in any of the approved forms of lever fire-brick presses in common use in the United States, or in the power press made especially for this purpose by the Frey Sheckler Co.

In England the screw press is commonly employed for pressing the brick.

Whatever form of press is used, care must be exercised that the press-box, cap and plunger are very accurately fitted, in order that the corners and the arrises of the brick will be perfectly formed and not have the slightest fringe on them.

The brick when in proper condition for burning are carried to the presses usually twenty at a time; ten brick being placed on each of the two boards which form the top of the wheelbarrow, which barrow is provided with springs which prevent jar and injury to the brick. The brick are taken from the boards and placed on the table adjoining the press. Here a man takes each brick and rubs the palm of his hand gently over the face of the brick which is to be enameled, so as to free it from all particles of clay and grit. This man then gives

the same face of the brick a light tap with a dresser, and next makes the face of the brick even and smooth by using a palette knife, commonly ten inches in length.

The man who is to press the brick takes it up with both of his hands and adjusts the brick on the press, keeping the face of the brick, which has been carefully prepared as above described, always towards him.

In order that the face of the brick which is to be enameled may not come in contact with the side of the mold-box, as the lower plunger descends, the presser should be careful to crowd the brick far back on the plunger plate. When the brick has been properly pressed, every corner and arris should be sharp and clean and perfectly formed.

After the brick have been pressed they are carried on a flat top spring barrow above described, to a drying room which there are series of racks arranged in rows on each side of the walk, about five feet in width left between the two rows of racks. These racks which are built of wood are fitted with board shelves placed one over the other, eight high, with six inch spaces between. This arrangement of rack and pallets is provided to receive the brick in order that they may properly dry after they have been enameled.

The boards forming the shelves should be one inch thick by eleven inches wide, and the racks can be any length which will suit the room. The racks should be divided into sections to hold fifteen brick on edge. In order to prevent the marking of the brick on the back as they are made to slide on the boards, the top surfaces of the boards should be dressed.

ENAMELING.

When the brick arrive in the drying-room from the press the brick are carefully taken from off the flat barrow, and if made by a wire-cut machine, it is necessary to polish the face or head to which the enamel is to be applied with a knife in order to close up all holes or cracks on the surface.

Brick made by hand are only brushed over the parts which

are to be enameled with a soft brush, as will be explained later.

The next operation consists in applying with a soft brush a preparation to the same portion of the brick before brushed.

In order, however, that the subject so far as it pertains to the preparation of the various glazes, "bodies" and stains may be fully understood, the writer will now describe their composition and explain the manner in which they are applied to the green brick.

GLAZE NO. 1.

18 lbs. Feldspar.
3½ " Cornwall stone.
2½ " Oxide of zinc.
1¾ " Whiting.
1 " Plaster.
Mix for use.

GLAZE NO. 2.

A little softer than No. 1.

10 lbs. Feldspar.
2½ " Cornwall stone.
1½ " Oxide of zinc.
1½ " Flint.
¾ " Lynn sand.
¾ " Carbonate barytes.
Mix for use.

WHITE BODY NO. 1.

36 lbs. China clay.
10½ " Ball clay.
6 " Cornwall stone.
3 " Whiting.
1½ " Flint.
1½ " Plaster.
Mix for use.

WHITE BODY NO. 2.

Not quite so white as No. 1.

12 lbs. China clay.
3½ " Ball clay.
3 " Feldspar.
1 " Flint.
Mix for use.

WHITE BODY NO. 3.

This is to be used with colors only.

18 lbs. Ball clay.
16 " China clay.
9 " Cornwall stone.
6 " Flint.
3 " Lynn sand.
Mix for use.

BUFF BODY.

18 lbs. Best fire clay.
16 " Ball clay.
16 " China clay.
8 " Flint.
6 " Cornwall stone.
Mix for use.

CREAM BODY.

28 lbs. Ball clay.
12 " China clay.
6 " Best fire clay.
8 " Flint.
4½ " Feldspar.
Mix for use.

IVORY BODY.

8 lbs. China clay.
6 " Ball clay.
6 " Flint.
3 " Feldspar.
Mix for use.

MAHOGANY-BROWN STAIN.

15 lbs. Chromate of iron.
10 " Manganese.
4 " Crocus martis.
4 " Oxide of zinc.
Fire hard and grind.

VANDYKE-BROWN STAIN.

3 lbs. Chromate of iron.
1 " Manganese.
¼ " Oxide of nickel.
Fire hard and grind.

YELLOW-GREEN STAIN.

12½ lbs. Flint.
8¾ " Whiting.
8½ " Bichromate of potash.
4 " Fluor-spar.
3½ " Red lead.
2¾ " Plaster.
Fire hard and grind.

RED-BROWN STAIN.

4 lbs. Oxide of zinc.
2½ " Red oxide of iron.
2 " Bichromate of potash.
2 " Flint.
Fire hard and grind.

LIGHT-BLUE STAIN.

10 lbs. Oxide of cobalt.
9 " Cornwall stone.
1 " Sulphate of barytes.
Fire hard and grind.

ORANGE STAIN.

5 lbs. Alumina.
2 " Oxide of zinc.
1 " Bichromate potash.
½ " Red oxide of iron.
Fire hard and grind.

TURQUOISE STAIN.

6 lbs. China clay.
6 " Oxide of zinc.
1½ " Oxide of cobalt.
½ " Carbonate of soda.
Fire hard and grind.

SAGE-GREEN STAIN.

2 lbs. Calcined oxide of nickel.
1 " of above turquoise stain.
Mix for use.

ROYAL-BLUE STAIN.

40 lbs. Alumina.
10 " Oxide of zinc.
5 " Oxide of cobalt.
4 " Lynn sand.
1 " Carbonate of soda.
Fire hard and grind.

BROWN STAIN.

2 lbs. Oxide of zinc.
1 " Bichromate of potash.
½ " Iron scales.
Fire hard and grind.

BLUE-GREEN STAIN.

8 lbs. Flint.
5 " Oxide of chrome.
4 " " " zinc.
3 " " " cobalt.
Fire hard and grind.

DEEP-BLUE STAIN.

13 lbs. Oxide of zinc.
3 " " " cobalt.
2 " Common soda.
9 " Flint.
Fire hard and grind.

CELADON STAIN.

12 lbs. Flint.
6 " Bichromate of potash.
8 " Oxide of zinc.
¾ " " " cobalt.
Fire hard and grind.

DRAB STAIN.

18 lbs. Flint.
3 " Whiting.
6 " Oxide of nickel.
2 " " " cobalt.
1 " " " chrome.
Fire hard and grind.

GRASS-GREEN STAIN.

15 lbs. Flint.
10 " Borax.
4 " Common soda.
14 " Oxide of chrome.
10 " " zinc
3¼ " " cobalt.
Fire hard and grind.

OLIVE-GREEN STAIN.

2½ lbs. Flint.
1¼ " Borax.
1½ lbs. Oxide of chrome.
1 " " zinc.
½ " " cobalt.
Fire hard and grind.

MAZARINE BLUE.

Dip the brick just as if you wanted them for white brick, but when ready for glazing take a pint of glaze and one ounce of light blue stain, mix them well together, run them together through a lauro and then dip the brick in this.

FIRST BODY USED.

This is called Dip No. 1 and must in all cases be used first, whether for colors or white. It is made as follows: ½ pound of white body, ½ pound of same clay as the brick are made of. To mix this body it is best to put some of your own clay into some *clean cold water*, pass it through a sieve (or brass lauro); brass lauro is by far the best, and must have 60 holes to 1 square inch; pass it once through this lauro. Then it requires to be passed through a sieve or brass lauro with 80 holes to 1 square inch at least 3 times; then take say 10 quarts of this and 10 quarts of white body, either No. 1 or 2, but in *no* case use No. 3 for this dip; if you are going to dip white brick in No. 1 white body, use No. 1 for this slip, and if you are going to dip into No. 2 white body use No. 2; if you are going to dip into both of these, then have some of both of these whites mixed separate with clay. But if you are going to dip in any of the colors, then use white body No. 1 for this body and white body No. 3 to mix with the colors, or you can use white body No. 1 with the colors if you wish, but you must add a little of Lynn sand to it, say ½ pound to every 20 pounds of the other. Before mixing the clay slip and white body together, they must both weigh 28½ ounces to a pint. This body is called Dip No. 1. White body and all colors are called Dip No. 2. Glaze is called Dip No. 3.

INSTRUCTIONS.

As soon as the brick leave the press take a *very soft brush* and stroke over the parts about to be enameled to remove all oil that may have got on while pressing (use paraffin and sweet oil to press with); after this take a *similar soft brush* (a very soft hat brush is the kind to use) and dip this brush into *Dip No. 1;* this is the receipt given made of one-half of your own clay and one-half of white body, and again stroke the same portion as before with this brush. Then dip the brick itself into *Dip No. 1*, then let them stand say for three or four hours, (but not drying). but just enough to take the moisture from the slip just put on, and whilst still moist (we mean the brick) dip again, this time into *Dip No. 2;* this is either the white or colors (see explanations); then let the brick dry slowly but thoroughly *white hard.* They must be thoroughly white hard, and when quite white hard they are ready for *glazing. Dip No. 3;* but before glazing them remove all dust, etc., that may have got on whilst drying, and also before dipping them in the glaze after the dust is removed they must first be dipped (the enameled portion only) into *clean cold water* and *immediately* into the *glaze.* Do not allow the brick to stand above one minute after dipping into the water before you dip them into the *glaze, Dip No. 3.* They are first dipped into the water to stop the brick from sucking up the substance from the glaze. You will see by this that they *must be immediately* dipped in the *glaze, Dip No. 3*, after being dipped into the water. They then require the edges or sides to be brushed with a wire brush (old cast-off from wool shearing will make these brushes) and are then, after being dried on the boards above described, ready for either kiln or oven. In placing them in the kiln or oven set them face to face, not to touch, say one-half or one inch apart, we mean the faces; the sides can go quite close together, and as far as possible put all whites facing whites and each color facing same so that the colors will not cast a shade on each other. In firing go very slow for the first twenty-six or thirty hours, then push up the fires gradually, not too quick, but when once

pushed up do not allow the fires to fall back again, and when the glaze has commenced to run they require about six hours gradual firing or when run quite smooth about three more fires to make them bright and clear. Do not allow the cool air to get into the kiln whilst cooling, or it will cause them to crack and craze, and do not draw the brick until quite cold.

Before any of the slips or bodies, glaze included, given are used they must be mixed with clean cold water and passed through a lauro, 60 to 80 holes to one square inch, at, least 4 times, and must weigh as follows: Dip No. 1, 28½ ounces to 1 pint; Dip No. 2, 28¾ ounces to 1 pint, whether white or colors; glaze, Dip No. 3, 28½ ounces to 1 pint after being passed through the lauros. When all the brick are set in the kiln or oven they should be covered up at the top to stop all the dirt and sulphur from the coal getting on them whilst being fired. You can fire these brick in either up or down-draft kilns, but must protect them as much as possible from the sulphur and dirt.

EXPLANATIONS.

The 2 glazes given are both transparent, that is to say, will show through any color, but to avoid being out it is best to add a little of each color to the glaze, when dipping colors, say ¼ ounce of color to every pint of glaze; of course you will know that they must be kept separate and when putting them through the lauro everything must be perfectly clean and clear from any other color; for everything in connection with glazed brick all must be kept strictly clean, and also *clean cold water* used. Where we say *mix for use*, we mean they must be put in either tubs or boxes water-tight, well mixed together, then put clean cold water with them, mix well up again, then run or put through the lauro as per dip No. 1 process, once through the 60 lauro and 3 times at least through the 80 lauro; they are then ready for use. The *buff body* will be a far nicer buff if you will use a little of the orange stain, after it has been fired and ground; say put 1 pound of color to every 15 pounds of the buff body, but it *must* be passed through the lauro

after this stain has been put to it. By *fire hard and grind*, we mean weigh the mixings as given in each receipt; pass them all through a very fine sieve—we don't mean a lauro: but a sieve about 16 or 18 holes to the inch; mix well up together; then put it all into a seggar or anything biscuit (we mean by biscuit anything that has not been glazed), but you should first put a coat of flint inside the seggar mixed with water; this will prevent the color or rather stain from sticking to the seggar, etc. Then put the seggar with the stain in the hottest place in your brick kiln and fire it; when it is fired you will find the flint and perhaps the seggar stick to it; it must all be chipped from the color; it then requires grinding; you should have a color pan for this purpose, but if you will send it to the potters they can grind it for you, as they must have color pans. If it is like cinders or clinkers when it comes out of the kiln, do not throw it away, for it is as it should be, but some of the colors will not go like this; orange will not, no matter what heat you go to. After it is ground it wants drying in biscuit basins or anything that is biscuit, then run through a very fine sieve; the finer the better, and it is then ready for use. You then take—for instance we say grass-green—you will take one ounce of grass-green stain to every ten ounces of white body No. 3, mix them well together, put some clean cold water with them, pass them through a sixty lauro once and through an eighty lauro three times, make it to weigh 28¾ ounces to a pint, and it is then ready to be used as Dip No. 2. You treat all the colors in this way. For turquoise, sage-green, deep-blue, royal-blue, brown and grass-green, use one ounce of stain to every ten ounces of white body No. 3. For Vandyke brown, red-brown, orange, blue-green, celadon, yellow-green and olive-green, use one ounce or one pound of stain to every 12 ounces or 12 pounds of white body No. 3. For mahogany brown use 1 ounce or 1 pound of stain to every 14 ounces or 14 pounds of white body No. 3. For drab use 1 ounce or 1 pound of stain to every 22 ounces or 22 pounds of white body No. 3. For light blue use 1 ounce or 1 pound of

stain to every 80 ounces or 80 pounds of white body No. 3. You must also stain the different glazes as we have before mentioned, viz. ¼ ounce of stain to every pint of glaze, but light blue is excepted; you must use 1 ounce of light blue stain to every ½ gallon of glaze, or it will be too deep a color. You will see we mentioned *calcined* oxide of nickel in the sage-green receipt. We mean by calcined that it must be fired. You will get it ready calcined and ground from any wholesale druggist. The turquoise stain and the oxide of nickel must both be calcined and ground before they are mixed together for sage-green stain; after they are thus mixed you must treat them just as the other colors, viz.: 1 ounce or 1 pound of this stain to every 10 ounces or 10 pounds of white body No. 3. Be very careful when weighing out the quantities that you obtain the correct weights, as in some cases ½ an ounce will throw you wrong either way. You cannot be too careful in weighing them out. You must in all cases put dip No. 1 on the brick first (see instructions); this is the slip made of your own clay and white body; then the white body is called Dip No. 2, that is to say if you want to make a white brick. For the second dip, dip it into the white body, but if you want to make any of the colors (mazarine blue excepted) you must put the colored body on instead of the white, and call that Dip No. 2. All materials used to make the stains you can obtain from any wholesale druggist; but the others, such as flint, feldspar, Cornwall stone, whiting, plaster, ball and china clays, you can obtain from the potters or from flint mills, or wholesale druggists should keep them: the potters should keep them, as they are obliged to use all the materials which we have mentioned in their own manufacture of pots, etc.

SETTING.

After the brick have been enameled and are perfectly dry they are taken from the boards in the drying room, and after being placed on the flat-top spring barrows, care being observed that the brick are so placed on the barrows as not to

touch each other, they are then carried to the kiln to be set. In the burning of enamel brick it has been found advantageous to set green fire-brick 8 or 10 courses high over the bottom of the kiln, as well as to set the green fire brick for burning around the sides of the kiln to the same height as it is intended to set the enamel brick. In this way the first flash of the fires comes in contact with the ordinary fire-brick, thus shielding the enamel brick. Care must be always taken in the setting of enamel brick to protect their enamel faces from the action of the flames as they pass through the kiln. The brick can be set on end, but the faces of the enamel brick must be closed in and protected from steam, smoke and sulphur during the firing process, and the brick should be set face to face, but never allowed to touch each other. The sides of the brick can be placed so as almost to touch, and as has also been previously stated, the brick which are enameled for white should face each other, and each color should face brick of the same color, thus preventing the chemical shading of the various colors which would be likely to occur under the action of high temperatures.

Any practical man who has had experience in this line of work will find no difficulty with the setting of the brick.

A correspondent who recently wrote us from England says: "The way I would set the enamel brick in the kiln for burning is on the 'board,' which is a technical term in England for a peculiar manner in setting brick, and means to stand the brick on end and then place a row of brick on the top of them, edge up. By this means the face of the enamel brick is closed in and forms a nine-inch wall. This wall is carried up to a height of four feet, and between each wall there is left a space of about three inches, which allows the fire to work its way up between the wall or 'boards,' and prevents the smoke or sulphur from the coal from reaching the enamel face of the brick."

KILNS.

The method of burning enamel brick with dead heat by plac-

ing them in seggars, or burning them in muffled kilns, which was practiced a few years since, is now no longer in vogue. The great cost for fuel and heavy expenses for repairs to kilns forced the abandonment of this method. Under no circumstances let any man prevail upon you to erect muffled kilns in which to burn enamel brick. Such kilns are not necessary, and the brick burned in them are in no way an improvement over the brick burned in round down-draft kilns. Square kilns are employed in some parts of England for the burning of these brick, but the round-down-draft kiln has the preference. In the firing of enamel brick it is necessary to have coal which is as free from sulphur as it is possible to obtain it.

FIRING.

The steaming or water smoking of enamel brick should receive the closest attention, as, without great care being exercised, it is possible at this stage of the work to ruin an entire kiln of brick. While the enamel brick are on the smooth boards in the drying room after being dipped, the exterior of the brick will become thoroughly dry, but considerable moisture will still be present in the centre of the brick when they are removed from the boards to be conveyed to the kiln for firing. If this moisture contained in the interior of the brick should be drawn too suddenly to the surface by subjecting the brick too quickly to a high heat, the enamel surfaces of the brick will be stained with a black-bluish streak down the center, thus rendering the wares unsalable. Other defects engendered by a too quick drying off of the moisture will result in flawed, cracked, shaky or burst brick.

When the water-smoke fires are started in the kiln, the heat should be raised very slowly, and at no period of the two nights and three days devoted to the drying of the brick in the kiln, should the grate-bars be more than one-half covered with fire. During the water-smoking of the brick, as much air as possible should be admitted into the kiln, and if the fire holes are provided with doors, these doors should be allowed to

stand wide open. After this preliminary stage is passed the intensity of the heat should be gradually increased, and by the third day all the brick in the kiln should be about red hot, and when once under full fire the kiln must not be neglected or allowed, under any circumstances, to cool down, but the fires must be steadily continued until the glaze has run bright. The test-proofs used should be in the shape of a cup with a hole in it so as to make them easy to draw from the kiln. This test-proof, both inside and outside, should be enameled and glazed. The trial pieces should be drawn out from each end or side of the kiln when on looking through the peep hole into the interior of the kiln the flame will appear to be one solid white mass; none of the brick being perceptible through the white heat.

An examination of the test-proofs at this stage of the burning, the proper enamels having been used, will show them to have a sweaty or greasy appearance, thus giving evidence that the enamel on the brick is in the incipient stage of fluxing. If the trial pieces have this sweaty or greasy look, then you must force your fires to their utmost, increasing the heat to as high a temperature as is possible, and in the meanwhile drawing out one of the test-proofs at intervals of about one hour to learn precisely the progress which is being made towards the complete fusion of the enamel.

Finally, when the test-proof has been drawn having a glassy smoothness of surface, the time is now arrived when firing must stop. All the fireplace doors and every part of the kiln through which cold air drafts could find an entrance into the interior should be carefully daubed so as to make the kiln perfectly air-tight.

COOLING.

The kiln must be allowed to cool very gradually; no aid should be given to the cooling process by opening doors or in making any channels through which the air on the outside of the kiln can enter it. The chimney must be depended upon to

cool the kiln, all dampers leading to the chimney being fully open so that the stack can do this work unhampered. This should be continued until the beginning of the sixth day, when the holes in the top of the arch of the kilns can be opened, caution being first exercised that all dampers in flues leading to the chimney are closed, and that all draughts about the kiln are stopped. In this way it is possible to draw all the heat from the kiln without danger of injuring the enamel brick. The wicket, however, should not be thrown down until it is possible, when putting the hand through the holes in the top of the arch of the kiln, to pick up the brick, which must be cool enough to handle with the naked hand. By following these directions in the cooling of the brick, " air cracks" will not be inflicted upon the brick, which lessen their market value.

The sorting of the brick is usually in three classes, and has reference to the condition of the enamel surfaces of the wares. First quality brick are true in shape, have perfect corners and arrises, and the enamel surface of such brick must have neither flaws nor cracks. Brick having cracks either visible or invisible or blisters form the second quality of wares. The third class of brick are those which cannot be sold for second, because they are either chipped or cracked, and the manufacturer who obtains for such brick the price of ordinary front brick is very fortunate. There is no profit in manufacturing either second or third grade enamel brick. The manufacturer who cannot produce at least seventy-five per cent. first-class enamel brick will find his profits absorbed.

The enamels, glazes and colors used in the manufacture of these brick can be obtained from either Messrs. Harrison & Son, Hanley, Staffordshire, England, or C. Bloor & Son, Burslem, England.

ENAMELING SLATE WASTE BRICK.

Some ten years ago, when first the manufacture of brick and tiles from slate waste commenced in North Wales, the white-glazed brick was successfully produced by the following process and recipes:

The process is called the Biscuit-brick process—that is, the firing of the brick only slightly at first, all care being taken in setting and drawing the bricks so as not to damage them in any way. The brick need to be fired at about half the customary heat for the first fire; they must then be taken to the dipping-house to be dipped in the body and glaze. Having everything in readiness, dip the part required to be glazed in clean water; you then pass on the brick to the next hand, whose dip will be the white body; then on to the next hand, whose dip will also be the white body; again, pass on the brick to the fourth hand, whose dip will be the glaze. Allow the brick to dry a little; then take a knife and scrape off all body and glaze that may have run over the side of the brick. The brick can then be set in the kiln to be fired again. The slate waste, however, is a ticklish material, and will not stand a hard fire. The heat it will take is a good red clay heat; it will thus be seen that a down-draft kiln will not do for glazing slate waste. It must be fired in a kiln where all the flash-heat can be kept from the brick—the kiln generally used is the Simmer muffle-kiln. The kiln itself when set with brick is almost a box-kiln. The brick must be fired gently at first, and when on full fire it must not be neglected or allowed to sink too low. The firing should be continued until the glaze has run bright.

The following are the recipes of body and white glaze:—

WHITE BODY.

74 lb. china clay,	17¼ lb. stone,
18 lb. flint,	3½ lb. plaster.

All must be mixed together dry, before adding water, on account of the plaster. Dip the brick at 30 oz. to the pint slop, and pass the body twice through a fine sieve.

WHITE GLAZE.

19 lb. feldspar,	½ lb. plaster,
6 lb. stone,	2½ lb. best flint glass,
1½ lb. whiting,	12 oz. white lead.
¾ lb. flint,	

Mix as above.

CHAPTER XII.

THE MANUFACTURE OF SEWER-PIPE.

THE clay from which sewer-pipe are made is a grade of fire-clay. Much care is required to be exercised by those who select the clay from which sewer-pipe are manufactured. The coarse, open, non-plastic clay used for fire-brick will not answer the required purpose. Earthenware pipe of this character require that the clay shall be plastic, so as to form a close homogeneous body similar to that used for architectural terra-cotta. It is also desirable that the clay should contain a large proportion of silica, which is of material assistance in applying the salt glaze, as will be hereafter explained.

There are two quite well marked ways of making sewer-pipe in the State of Ohio, which leads to their classification usually as the river process (that used in the Ohio Valley in Jefferson county), and the Akron process (used at Akron and Columbus). The process is the same in all cases, and even extends into the manufacture of fire-brick as far as the grinding and tempering goes.

When the clay has been ground, sifted and tempered, it is usually elevated by a belt to the upper story of the works, and deposited in a bin beside the top of the sewer-pipe press. All sewer-pipe machines act on the same principle, but the mechanical details differ.

The pipe-press consists of a large steam cylinder, upon a high iron frame; the piston runs into a second cylinder of less diameter situated beneath it; this is called the mud-drum or mud-cylinder, and into it the clay to be pressed is introduced, and from its lower end it is forced out as pipe by the pressure from the upper or steam cylinder. The piston at the upper limit of the stroke leaves a passage into the inside of the mud-

drum near the top, which is closed as the piston moves down further. Into this opening is shoveled the tempered clay. It is tempered so dry that it may be shoveled with perfect ease, and it has no tendency to stick together by contact alone, though it does so readily by pressure. The cylinder being filled with clay, the piston is given steam and moves down slowly, consolidating the clay and expressing the inclosed air through small holes in the piston-head and the cylinder bottom. When, through these holes, the clay begins to issue, the pressman knows that the clay has filled the shape of the cavity perfectly; and as the bottom is a movable one, it is loosened and dropped upon a balanced platform close beneath it. This platform under the weight of the cylinder head, which is so shaped as to form the pipe, is just counter-balanced, and by any pressure can be moved up or down, carrying the socket shaper on its top. The bottom being pushed out of the way, continued pressure from above causes the pipe to issue. When enough has come out, it is cut off by a rotary knife from the inside, and the separated length of pipe is carried away either on a cart or in the hands. It is next sponged and pared, to smooth it. The pipe is shaped by being forced out between the walls of the mud-drum and a conical core which is suspended from higher up in the drum. This cone parts the clay evenly on all sides, and causes it to leave the press in an even, regular shape and thickness. The dimensions of the presses used are various; the Pittsburgh press at Walker's has a steam cylinder 44 inches in diameter, and 23 inches of mud-drum. The ordinary diameter is from 35 to 36 inches, and about 18-inch mud-drum.

The river works make this pipe just as easily as they do the thinner kinds, and they claim an advantage here over their competitors who make no thick pipe.

The differences in the manufacture of pipe in the Akron and Columbus district from the river process begin in the material employed. The grinding machinery of the Akron district consist of the machines called tracers. The tracer is an excellent

machine for grinding a true clay of a sandy or plastic nature, and though its work in shale is successful, yet it seems as if the heavy wet mill of a fire-brick works could not fail to be better. It would at any rate grind much more in the same time than the tracer, if it did not grind it any better. The fracture of an Akron made sewer-pipe shows frequently small pieces of shale which have escaped the wheels, and in burning, these pieces usually shrink away from the bond clay so as to make a loose spot in the pipe, and they are consequently weakening in their effect.

There is in use among railroads and such companies a kind of pipe which is especially fitted for their purposes. It is called among manufacturers the Cincinnati Standard, and the point of difference between it and the ordinary pipe in the market is in the thickness of the shell, making a 24-inch pipe 2 inches thick instead of 1¼ inches, as usual. The gang necessary to run a press are: 1st, one man to fill the mud-cylinder; 2d, one engineer; 3d, one man to cut the pipe and help handle the pipe; 4th, one man to manipulate the socket shaper; 5th, from one to three men to carry off the pipe. At one of the Eliottsville works, a press is in use having two mud-drums parallel, which are filled and pressed alternately, so that the press may work constantly instead of filling, pressing, and waiting to refill. The drums are shifted backward and forward by a horizontal cylinder to one side. The capacity of a press varies with the kind of clay used, the size of pipe made, and many other conditions, but in normal working, will not vary far from these figures; 36-inch press, making 6-inch pipe, 3,000 feet a day; 12-inch pipe, 1,000 feet daily; 15-inch pipe, 800 feet; 18-inch pipe, 650 feet; 20-inch and 24-inch pipe, about 500 feet daily.

The heat used in sewer-pipe burning is only that necessary to get a good salt glaze; about one barrel of salt to a kiln is required. Coal is the fuel invariably used.

The process of glazing with salt is of ancient origin, and it consists in throwing the salt into the kiln towards the end of the firing, and just before the highest heat is obtained.

Salt that has been used for pickling can be employed, as it is not requisite that it should be pure.

The fires should be properly managed, and at the right temperature, in a closed kiln or oven; the salt is thrown uniformly through the holes at the top of the kiln. Small, light scoop-shovels are best for this purpose. The quantity of salt necessary for a moderate-sized oven is 150 to 160 pounds. About one-half the quantity of salt having been thrown into the oven, the fire is momentarily increased, then reduced, and a few specimens of clay burned with the pipes are examined, for the purpose of testing the glaze. The remainder of the salt is then thrown in, part at the top of the kiln, and part regularly over the top of the fire.

The temperature of the kiln is so high at the "burning off," or end of the firing, that the volatile salt is at once converted into vapor, which intimately surrounds the pipes in the kiln, and there is consequently a reaction of the vapor on the silica of the clay bodies.

The agent which promotes the reaction of the silica and common salt is the aqueous vapor which is always present in the flames of the furnace. The oxygen of the water produces soda with the sodium of the common salt, while the hydrogen combines with the chlorine, and is evolved as hydrochloric acid. The soda then enters into combination with the silica and forms the glaze.

The glaze produced upon the earthenware pipes in the manner described is consequently a soda-glass, and forms a very thin film or coating upon the material. It is of course manifest that the greater the quantity of silica a clay contains the more readily will it decompose salt, and the more lustrous will be the glaze produced. When it is desired to secure the brown color so common on drain-pipes, it is communicated to the glaze by throwing such substances as birch bark into the fire during the glazing process, and the larger volume of smoke thus evolved produces the desired effect. It sometimes happens that the ware in some portions of the kiln becomes covered with salt, a part of which then appears as an efflorescence.

After the kiln has been properly fired all the doors and openings are carefully daubed around with a mixture of sand and clay, a few air-holes in the furnace-doors not exposed to the wind being allowed to go unplugged for a few hours, and after two or three days the burned and vitrified sewer-pipe is ready to be removed and shipped to market.

The finished sewer-pipe are stacked up in piles ready for sale. The fittings which go with the pipe, such as curves, elbows, **S**-traps, **T**-pieces, **X**, **Y** and **U**-pieces, etc., are made for the different sizes of pipes; they are separately moulded and are more expensive than the lengths of pipe, as they are made mostly by hand in plaster molds, and all the other special shapes. The "river pipe" manufactured in Ohio are made from a homogeneous clay; *i. e.*, the clay by the nature of the preparatory steps, is reduced to a fine, even state of division, and by the character of the tempering plant is made into a perfectly uniform paste. And as it enters the pressing chamber in a comparatively fine state, the force which compresses it does not make the lines of demarkation between the particles which composed the mass apparent, as it would if the clay were not as soft as it is, and as finely divided. So when a piece of river pipe is broken its fracture shows an even, fine-grained structure, not so fine as stone-ware, but very similar and varying from a buff to a grayish-blue. This latter is the best tint to get, as it insures the combination of whatever impurity the clay contains with the free sand, and development of the best qualities of the clay. The use of salt makes the color a necessity, as a rule, for the combination of iron always begins before the glazing by salt vapor does. The strength that these pipe have is far in advance of any other Ohio pipe, as the structure, seen on the fracture, would show. The degree of heat which the clay will stand without injurious effects is far above the glazing heat of the pipe, and the only precaution in the burning to be observed is to secure enough heat with no close limit on the side of excess. The iron found in these Kittanning clays is present in small grains, which, under the action

of the salt glaze, make unsightly black blisters and holes in the surface, though in no degree injuring the utility of the ware. This feature has hitherto much injured its popularity. It is beginning to receive more credit than ever before, because its superior strength and durability are now being recognized. The color of the river pipe is light-red; in spots, where the heat did not get access to it, it is light buff, and in over-burnt portions a dark-red color, which has not a pleasing effect. The even, beautiful red color of the Akron and Columbus pipe have been the secrets which have given them their popularity above other kinds, but experience teaches that the color is not essential to the best results. The river pipe, on account of their light, red color, and mottled, spotted appearance, have not had popularity in the West, particularly in Chicago, the greatest of all markets, but they are constantly gaining ground there.

The grinding takes from forty-five to fifty minutes, and about 1,200 pounds constitute a charge; the water used is added by the bucketful, and the clay is tempered very stiff. In many works they use only two-thirds as many machines as necessary, and run part of their plant all night to get the necessary clay for the next day's campaign. The ground clay is shoveled into a squeezer either of the screw or piston type, and it is concentrated into a long compact cylinder about 6 inches or 8 inches in diameter. This is cut up in lengths of about 15 pounds weight, and is fed to the machine in that shape. From this results the worst trouble of the Akron pipe; the stiffness of the clay and the large, well-compressed wads in which it is fed, act together in keeping the clay from uniting to a homogeneous mass. Even under the powerful pressure of the machine, the lines of demarkation between the different pieces going to make up a pipe are plainly to be seen on the fracture of a burned pipe. They are arranged in circles concentric to the outside of the pipe, and often a crack of one-sixteenth of an inch separates the layers of the clay. This is all developed on burning, but is not visible before to any such degree. The

working of the clay is admirable. It issues from the press as smooth as if moulded with oil, and the sockets are beautifully true and correct. The drying, setting and burning need no special attention. The kilns used are the same as are used for burning stone-ware; they are oblong, end-fired down-drafts, about 30 to 35 feet long, and 15 to 20 feet wide, with an average capacity of about 40 tons. The burning takes six days.

The character of Akron sewer-pipe-ware has already been hinted at in the description of the river pipe. It is a smooth, handsome ware, well-shaped, of a beautiful dark red-brown color, and remarkably uniform. On its fracture it shows the red color of a brick or even a darker red, which demonstrates the presence of iron in that peculiar state so hard to define, which is necessary to the development of the high color; the per cent. of iron must be high, yet but little of that offensive blotching seen on the river-made ware can be noticed. The weakening of the whole structure by the concentric cracks due to the pressing is the worst fault of the pipe.

As to the inability of the Akron works to make the Cincinnati Standard pipe, this is to be said: The increase of thickness of their pipe, with the same amount of drying which they now give it, is liable to cause large flakes to spall off from the sides of the pipe when heated in the kiln. With a longer and hotter drying they could make these thick pipe, but as their capacity is used to the fullest rate now, they are under no necessity to begin its manufacture. One point where they hold a decided advantage over the river district, is the use of the patent device for making curves, elbows, S's and traps. They can control the position of the core inside the mud-drums by a lever, and by moving it so as to make one aperture smaller than the other, the clay issues the fastest on the thinnest side and the pipe takes a curve shape. Also by using a softer clay on one side than the other, the softest part issues faster and the pipe curves. The movable core is so nicely manufactured that such curves as the letter S, and the stench traps, can be made without help from the hands. This is a patented principle, and the

Akron works have a monopoly on it, and refuse to share with other parties.

The catalogues and circulars of the Akron manufacturers claim that they sell a *vitrified* pipe. But the word *vitrified* has a definite signification. It would require, if properly applied, that the clay should have been fused to a glass, or that it should have undergone incipient fusion, or that its free silica and fluxing impurities should have been made to combine. But none of these conditions are met. The fracture of the Akron pipe is not in the least vitreous. On the contrary, particles of the mass, such as pieces of shale, can frequently be seen separate and distinct from the body clay. The color also of combined oxide of iron and silica is dark, running from blue to black, while the color of uncombined oxide of iron is red: the color of the Akron pipe is red, showing that the impurities are not in a state of combination. But though the pipe is not vitrified, it is probably better than if it were, for the excess of the iron in the clay would tend to make it brittle, if it were in real combination. In other words, vitrification would present not only an undesirable but a dangerous quality in the sewer-pipe. Judicious experimentation with powdered feldspar, salt. potash solution, or any fluxing agent would very soon establish the practicability and test the advantage of making the vitrified pipe throughout. The Akron, Ohio, sewer-pipe have as wide a distribution as any other similar manufactured product in Ohio: they go in all directions and in all quantities.

Frederick H. Robinson, C. E., gives the following description of the manufacture of sewer pipe by the Delaware Terra Cotta Co., of Wilmington, Del.:

"The works are situated on Brandywine Creek, between Heald and Eleventh streets, and close to the Philadelphia, Wilmington and Baltimore Railroad. They are equipped for the manufacture of all the standard sizes and shapes of sewer pipe, as well as of other work in terra cotta, and of fire-brick.

"The material of which the pipes are made is composed of three ingredients—two kinds of clay, and a sand and clay

mixed. The first is a very strong clay obtained from brick yards in the northeastern part of the city. It underlies the clay of which brick are made. The second is a strong clay containing a red coloring matter, and is obtained from the south side of the Christiana River in New Castle Hundred, near the bridge on which the Delaware Railroad crosses the Christiana. The third ingredient is a material composed of fire-clay and sand, and is obtained on the Christiana River in New Castle Hundred. These ingredients are mixed in the proportion by measurement of two parts of the strong clay first mentioned, one part of the clay containing the red coloring matter, and one part of the fire-clay and sand. Made in these proportions the mixture is placed in the wet-pan, where water is added. The wet-pan is a shallow circular iron pan, in which the clays are crushed and mixed by two iron wheels, following each other on edge around the pan, driven by a horizontal axle attached to a vertical shaft. This pan is placed on the ground floor.

"After the materials are properly mixed, this clay is turned by a suspended shovel into the buckets of the elevator, which are attached to an endless band, in which it is raised to the third floor of the building.

"Projecting from the third floor towards the second is the casting which contains the iron mould for the pipe. Into this the clay from the wet-pan is thrown, and an iron plunger, moved by the piston of a steam cylinder, which piston is attached to the upper end of the plunger rods, descends vertically, compressing the clay in the mould below.

"After the clay is thoroughly compressed in the mould, an iron table under the mould, attached to the upper end of a piston passing below the second floor, and forming, as it were, the bottom for the mould, descends with the pipe standing upon it. The alternate upward and downward motions of the piston which moves the plunger, and the piston which moves the table, are controlled by the operator on the second floor, where the pipes are removed from the mould.

"Pipes under five inches in diameter are, when taken from the mould, immediately removed to another part of the second floor, where they have placed in them a wooden frame of the proper length, to which their ends are trimmed off and then smoothed with leather. As those over five inches in diameter come from the mould, they immediately have their spigot ends trimmed off, and are then taken by an elevator to the first floor where their ends are finished up. These, with the smaller pipes from the second floor, are placed on end on the drying floor of the first story of the building, where they remain from three to six days, when they are ready for burning.

"Branches are made by placing the branch piece, while damp, upon the main pipe, and then trimming and shaping them.

"Traps are formed by hand in plaster-of-Paris moulds, which are made in halves, dividing lengthwise.

"The walls of the kilns are of brick and are 13 inches in thickness. The kilns are circular, the largest being, inside, 22 feet in diameter, and 8 feet high to the square, surrounded by a dome.

"The kiln is filled with pipes from the drying floor, placed on end. It is fired from eight fire-places at equal distances around the kiln. Gas coal is used. Inside, the products of combustion pass through short vertical stacks toward the top of the kiln, whence they are beaten back among the pipes, and finally escape through a flue built around the kiln near the bottom, and pass in an underground flue to the stack.

"At the proper stage of burning, which is ascertained by small test pieces of clay which may be drawn and examined, the attendant passes three times around the kiln, and each time throws into each fire-place a shovelful of common salt. By this the pipes are glazed.

"After the scaling of the kiln three days are required in which to fire up and burn, and three more in which to cool off and remove the pipes, which are inspected and are then ready for the market."

MAKING CURVED EARTHENWARE PIPES OF EQUAL THICKNESS ON ALL SIDES.

The curves, elbows, and traps for sewer-pipe are now also made by machines especially constructed for the purpose, which are so arranged that by moving a plate placed over the mouth of the die the clay can be made to issue more rapidly from the opened side than from the other. The curve is formed in the pipe toward the side on which the space is contracted. By sliding the plate on the other side, the pipe will curve in an opposite direction, and by a succession of movements of the plates any desired form of curve or trap can be made.

The machine shown in Figs. 136 to 138 is the invention of Mr. Horace B. Camp, of Cuyahoga Falls, Ohio, and relates to the formation of curves, elbows, and traps.

Fig. 136 represents a central vertical section of a portion of an ordinary cylinder and attachments for making pipe and embodying this invention.

To the cylinder *A*, from which the clay is pressed to form the pipe, by a piston (not shown), is bolted a cylinder head *C*, made converging to facilitate the descent of the clay. To the head *C* is bolted the outside hollow die *D*, having an inside diameter at the bottom of the size of the desired pipe, and within which, supported centrally by means of the rod *F*, is the core *M*, having an outside diameter of the size of the inside of the desired pipe. Between the die *D* and head *C* is a chamber or recess, in which is fitted a plate *P*, Fig. 136, free to slide longitudinally in one direction at right angles to the main cylinder and core, and moved by means of a hinged lever, as will appear from Fig. 138, which represents a transverse section of Fig. 136 at the bottom of the plate *P*, looking from below. Through the plate *P* is an orifice of the shape, and approximately of the size, of the pipe to be made, within which the mandrel is suspended, and having the edges beveled from the upper surface outward. When the plate *P* remains so that the core *M* is exactly in the centre of the orifice therein, the clay descends with the same rapidity on all sides of the core, and is discharged in a continuous straight pipe. By sliding the plate

to one side, the space *S* between the edge of the orifice in the plate *P* and the mandrel is lessened on one side, and correspondingly increased on the other. The result of this is that the clay descends and escapes more rapidly on the opened side of the mandrel than on the side where the space *S* is contracted, and as it is discharged from the die *D*, it curves toward the

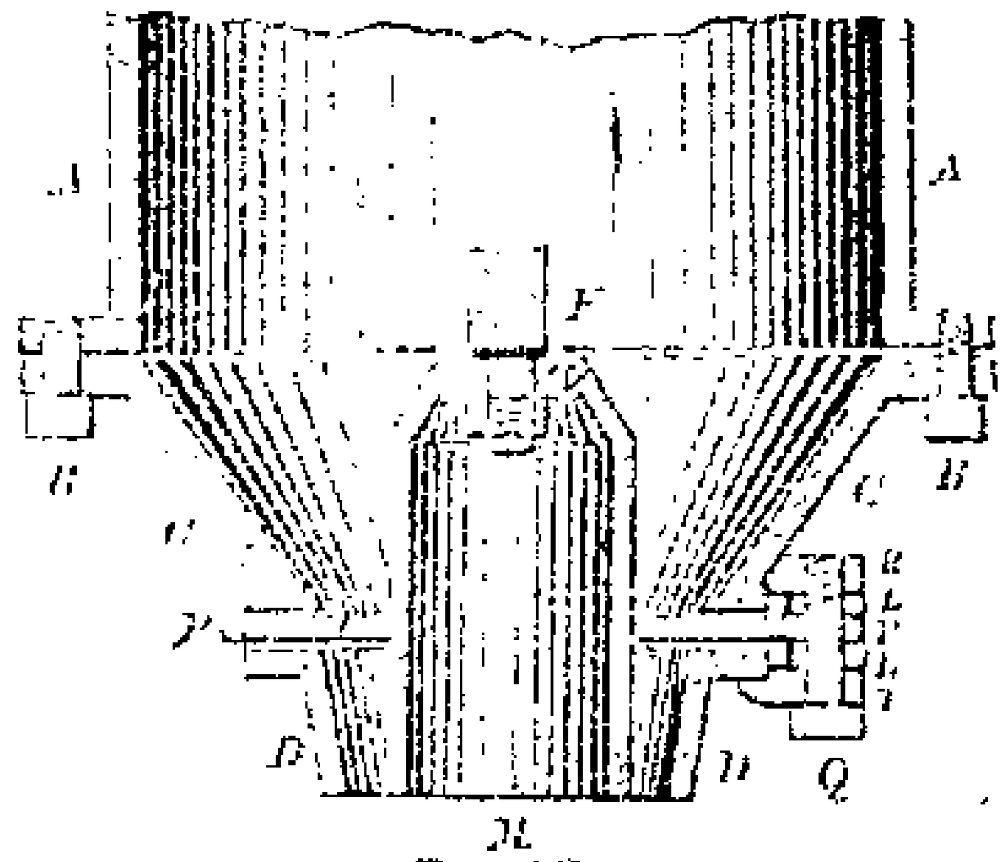


FIG. 136

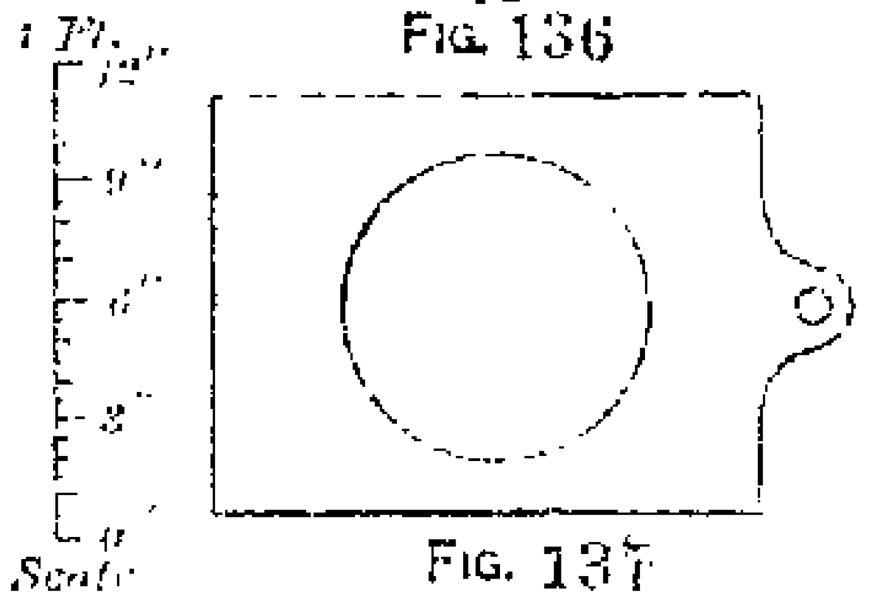


FIG. 137

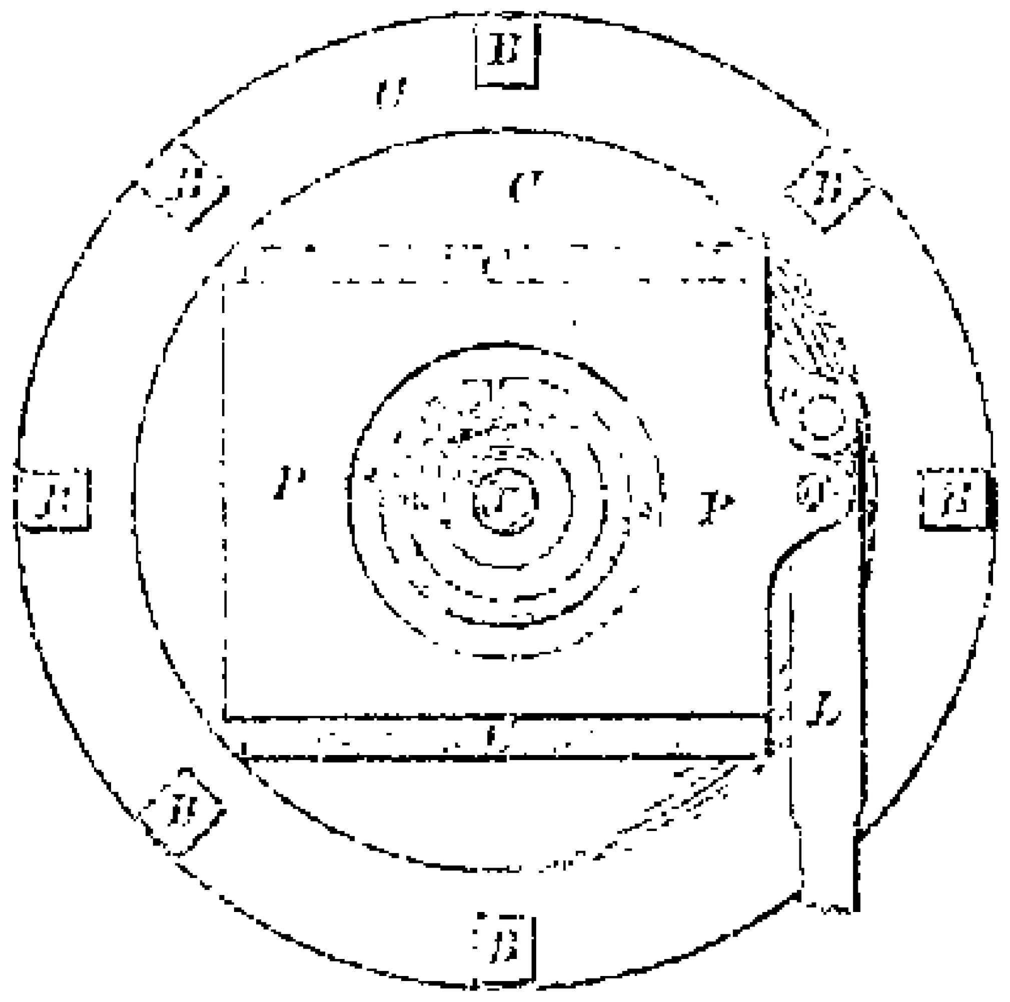


FIG. 138.

side on which the space is contracted. By sliding the plate to the other side, the pipe will curve in an opposite direction, and by a succession of movements of the plate, any desired form of curve or trap can be made. The relative positions of the die *D* and core *M* remain at all times unchanged, and as a result the pipe is of equal thickness on all sides.

The principle of curving such pipes, by allowing the clay to discharge more freely on the one side of an annular orifice than

on the other, is not new. Nor is the idea new of making parts of a pipe-machine movable at the will of the operator while the pipe is issuing, thereby enabling him to make reverse or other compound curves, as several devices have been invented and patented for moving either the die *D* or core *M*, while the pipe is forming. But all these devices have reference to a change in the annular opening between the core *M* and die *D* at the point of discharge, and herein they differ radically from this, in that the pipe is of uneven thickness on different sides.

MACHINES FOR FORMING SOCKETS ON CURVED EARTHENWARE PIPES.

The contrivances employed for forming sockets on curved earthenware pipes are also very ingenious, and in order to explain the machine used for this purpose it is necessary to state that ordinarily to form such sockets on sections of straight pipe, the outer die is prolonged beyond the point of discharge of such length and inside shape as to form the outside of the desired socket. When, however, the pipe curves as it issues from the orifice, this device is impossible, as the issuing pipe encounters the edge of this socket-die and is destroyed. In order to obviate this difficulty the socket-die is constructed separately from the other parts of the machine, in the form of a ring, divided into two parts, so as to permit of its being removed. By means of a lever this ring is firmly held in place until the socket is formed, when by a combination of arms and links the ring is opened automatically, and the socket having been formed, the curving of the pipe is proceeded with.

The machine shown in Figs. 139 to 145, is also the invention of Mr. Horace C. Camp, of Cuyahoga Falls, Ohio.

The invention has relation to that class of machinery for making pipes of clay, or other plastic material, by pressing it through annular orifice between an outside die and an inside core, and its object is to form sockets on the end of sections of such pipe when the pipe is caused to curve as it issues from the orifice.

In order to present the distinctive features of the invention it is proper to state that ordinarily to form such sockets on sections of straight pipe, the outer die is prolonged beyond the point of discharge of such length and inside shape as to form the outside of the desired socket. When, however, the pipe curves as it issues from the orifice, this device is impossible, as the issuing pipe encounters the edge of this socket-die and is destroyed. To obviate this difficulty, Camp constructs the socket-die separate from the other parts of the machine, in the form of a ring, divided into two parts, so as to permit of its being removed; and the first part of this invention relates to the method of holding this severed ring firmly in place until the socket is formed, which consists in fitting its upper edge into a groove in the lower face of the outside die, and its lower edge into a groove in a flange projecting from the base of the die, which forms the inside of the socket; and the second part of the invention relates to a combination of arms and links for manipulating the parts of the ring.

For the purposes of this description, we adopt the following nomenclature:

That part of the pipe-press which forms the outside of the annular orifice through which the pipe issues—the outside die. The piece suspended centrally within this, and which forms the bore of the pipe—the core. The die which forms the inside of the socket—the lower die; and the severed ring which is interposed between the outside die and the flange of the lower die, and forms the outside of the socket—the ring.

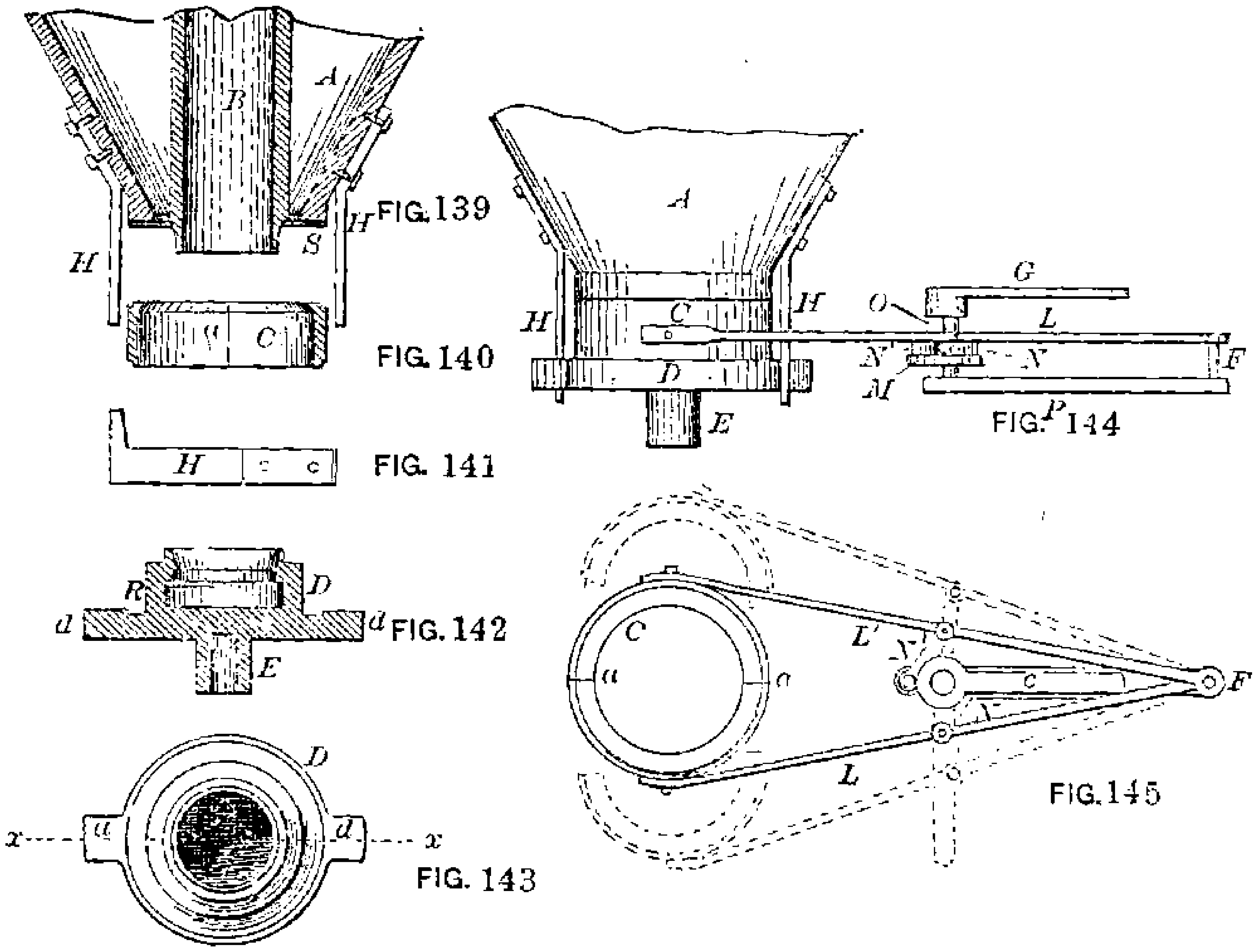
Figure 139 is a sectional view of a portion of the lower part of a pipe press, wherein *A* is the outside die, and *B* the core; the outside die *A* having a groove *S* in its lower face to receive the upper edge of the ring.

Fig. 140 is a central section of the ring *C*, divided in half at a line *a* (a plan of which is shown in Fig. 145), and having its upper edge turned to accurately fit in the groove *S*, in the outside die *A*, and its lower edge fitted in the same manner for the groove *R* of the flange of the lower die *D*.

Fig. 141 is a side view of one of the hooks *H*.

Fig. 143 is a plan, and Fig. 142 a section of the line *x x* of the lower die *D*. Upon alternate sides of the flange of this die are two lugs *d d*, which lock into hooks *H H* attached to the outside die *A*, and hold the several parts together while the socket is formed.

In operation, the lower die *D*, by means of the collar *E* projecting from its base, rests upon a following rod (not shown), which moves in the line of the axis of the press. The ring *C* is then placed thereon, with its lower edge fitting into the groove *R*. The whole is then raised to the press, the upper part of the lower die *D* joining, and forming a continuation of the core *B*, and the ring *C* entering into the groove *S*. The



lower die *D* is then revolved until the lugs *d d* lock into the hooks *H H*, as shown in Fig. 144, the whole forming a complete mould for the socket. When the socket is formed the lower die *D* is withdrawn, and the ring *C* separated and removed.

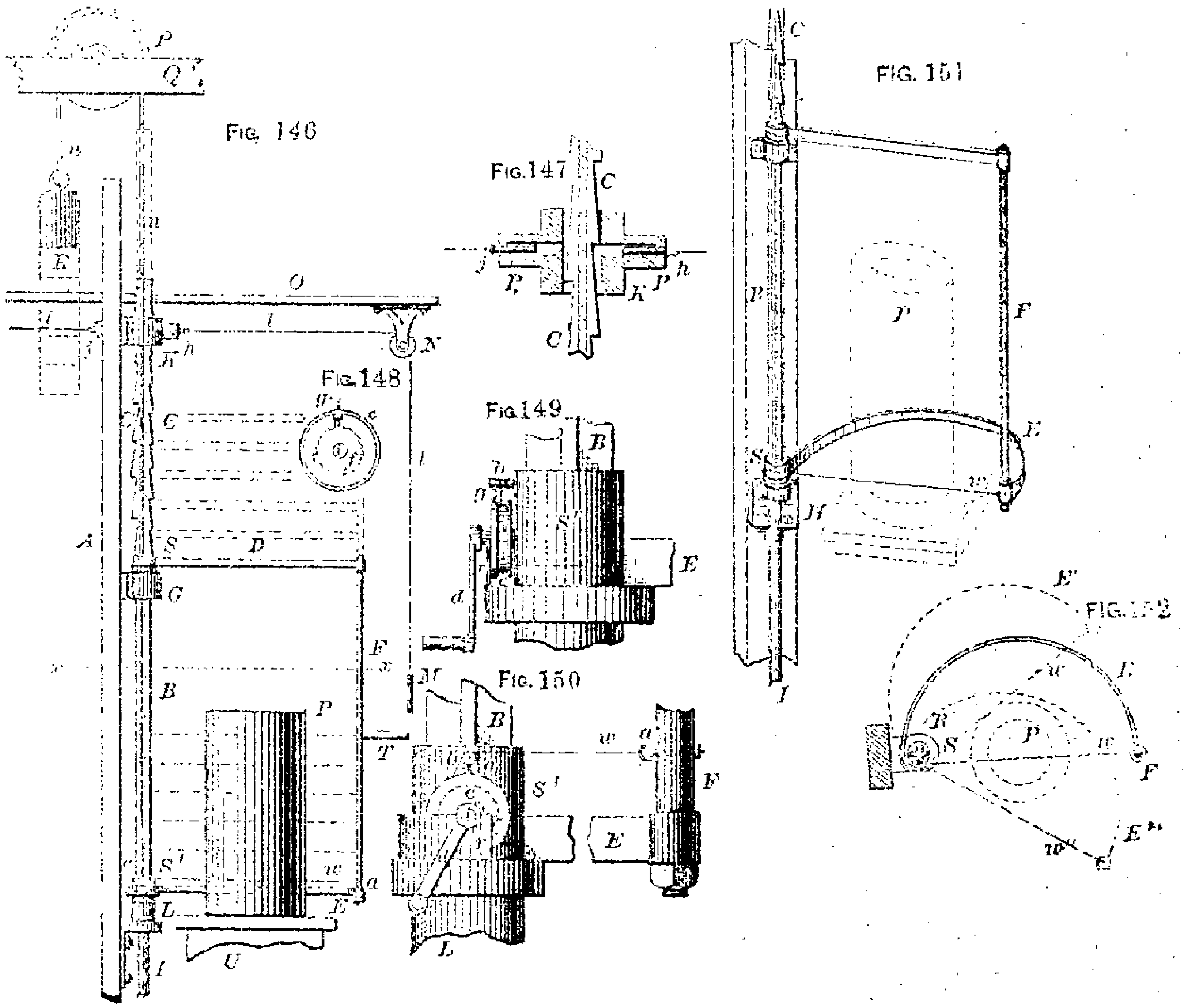
To facilitate the manipulations of the ring *C* the inventor attaches to the segments thereof the arms *L L'* (see Figs. 144

and 145), hinged upon the wrist F attached to the bar P. Upon the wrist O, journaled in the bar P, are fastened the lever G and link M, and opposite ends of the link M are connected with the arms L L' by the links N N', the whole so arranged that, by revolving the lever G, the arms L L' may be caused to diverge or approach each other, carrying the segments of the ring C.

The simple dividing ring C, for the purpose of making sockets on sections of straight pipe, is not new, but the method is new of holding it by means of the grooves in the dies A and D, and manipulating it by means of the arms L L' and attachments.

MACHINE FOR CUTTING SEWER-PIPE RINGS.

The machine shown in Figs. 146 to 152 is for cutting rings



from clay-pipe while in the green or undried condition in which they are formed; and which rings are designed, after burning, to be employed in the construction of drains and sewers. The invention consists in a horizontally vibrating wire-carrying frame arranged to swing over a suitable pipe-supporting platform, and capable of being moved vertically between each vibration and supported in place during each motion, so that the pipe is divided by vibrating wire into successive rings.

Figure 146 is a side elevation. Fig. 147 is a vertical section through the upper socket, showing the catches which support the racks and wire-frame. Fig. 148 is a sectional view, showing the ratchet of the wire-reel. Fig. 149 is an end view of the wire-reel on an enlarged scale, showing its mode of attachment to the lower arm of the wire-frame. Fig. 150 is a side view of the same. Fig. 151 is a perspective view. Fig. 152 is a sectional view on the line *x x*, Fig. 146.

A, Fig. 146, is an upright post or other suitable support, to which the swinging wire-carrying frame is attached by means of the lugs or sockets *L G K* and the sliding-bar *B*.

P is the pipe, resting on the fixed platform or stand *U*, and *w* the wire strained on the swinging frame, by which the pipe is cut.

R is a counter-weight, by which the swinging frame is balanced; and *C C′* are the racks, and *h j* the catches by which the length of the rings is determined.

In order to provide for cutting rings of different lengths, two or more racks *C C′* are made on the upper end of the bar *B*. The distance between the teeth of these racks corresponds with the desired length of the rings to be cut by the machine.

The frame may be made of sufficient strength to sustain the wire *w* without the curved arm *E*; but it is preferable, for the sake of lightness, to employ it. Where it is not used the two rings *S* and *S′* should be connected by an upright bar, so that they oscillate together.

In order to prevent loss of time consumed in replacing the

wire when it is accidentally broken, the inventor attaches to the ring S' a reel c, Figs. 149 and 150, about which a supply of wire is wound.

In the practical operation of this improved pipe-cutter, one or more of the pipes which it is desired to cut into rings being placed upright on the platform U, the operator swinging the frame backward and forward from the positions indicated by E' w', Fig. 152, to E'' w'', passes the wire through the pipe and severs it. At each end of the oscillating motion of the swinging frame, it is raised upward, or depressed for a distance corresponding with one of the teeth of the racks C or C' occupying in succession the positions indicated by the dotted lines in Fig. 152, and cutting a ring from the pipe while moving in each direction. A number of pipes may be cut into rings at one time, if placed on the ptatform U. After the completion of the cutting operation the rings, which remain on each other, are removed, and the process repeated.

It is preferable to commence the cutting operation at the lower end of the pipe, moving the frame upward between each cut, and using the handle M only, to disengage the dog h from the rack C, when it becomes necessary to depress the swinging frame.

A CONTRIVANCE FOR PREVENTING THE DISPLACEMENT OF DRAIN-PIPES IN THE KILN.

The contrivance shown in Figs. 153 to 157 is the invention of Mr. John Murtagh, of Boston, Mass., and is for holding or binding the upper course of pipes during the process of burning, and the application of this arrangement in works of any magnitude cannot fail to result in considerable savings.

The object is to prevent the displacement of the pipes when in the kiln; and the invention consists in securing each pipe of the top tier in the kiln to its neighbors, by means of binders made of clay like that of which the pipes are made, and baked or burned in the usual manner. Figs. 153 and 154 are diagrams, Fig. 153 illustrating the new mode of securing the top

tier of pipes in one way, and Fig. 154 in another, both ways of arranging the top tier being in common use.

Figs. 155*a*, 155*b*, and 155*c* show three forms of binders.

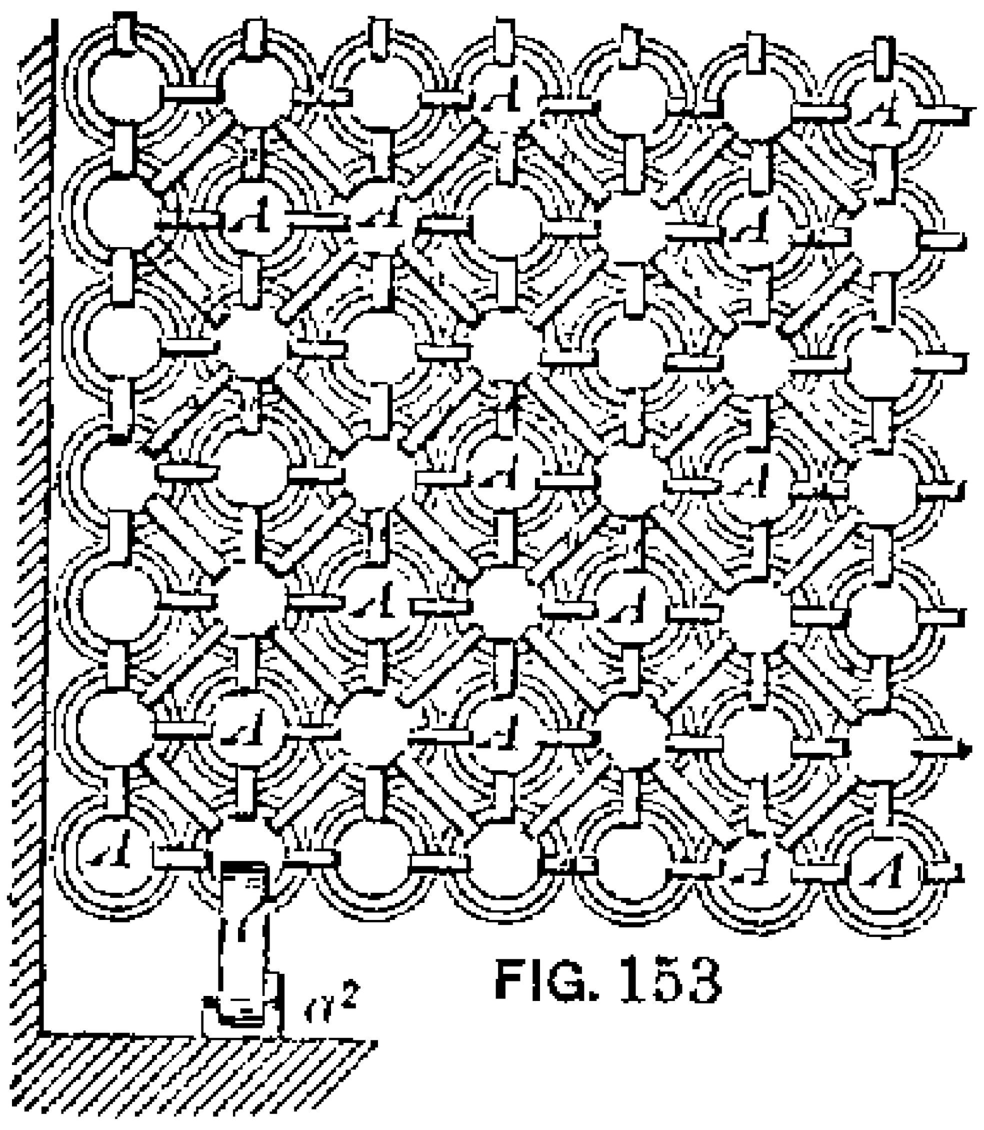


FIG. 153

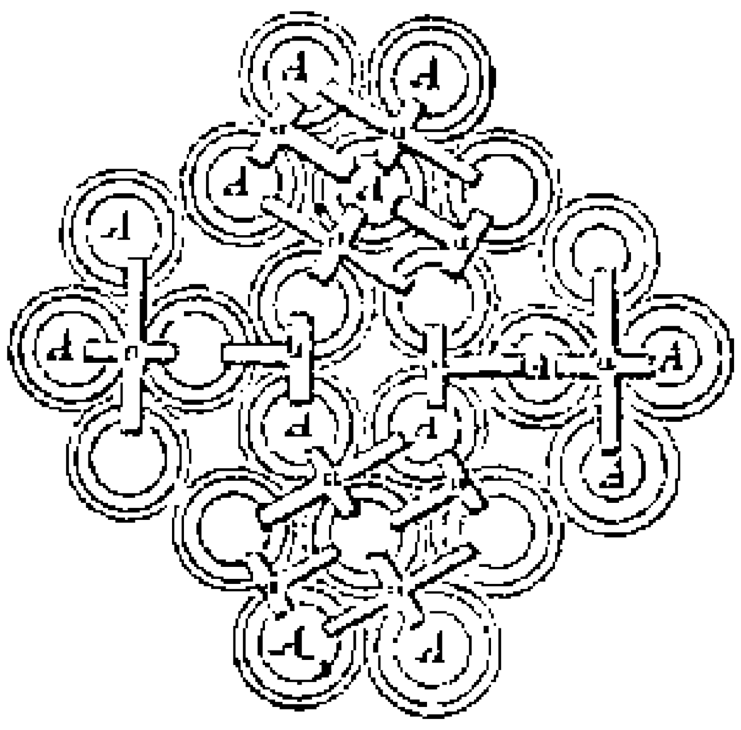


FIG. 154

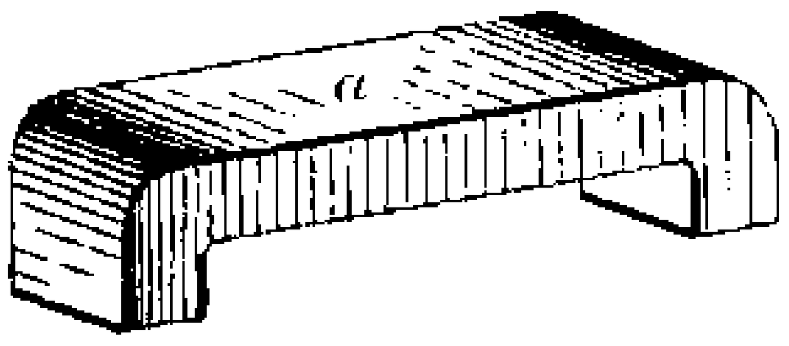


FIG. 155*a*

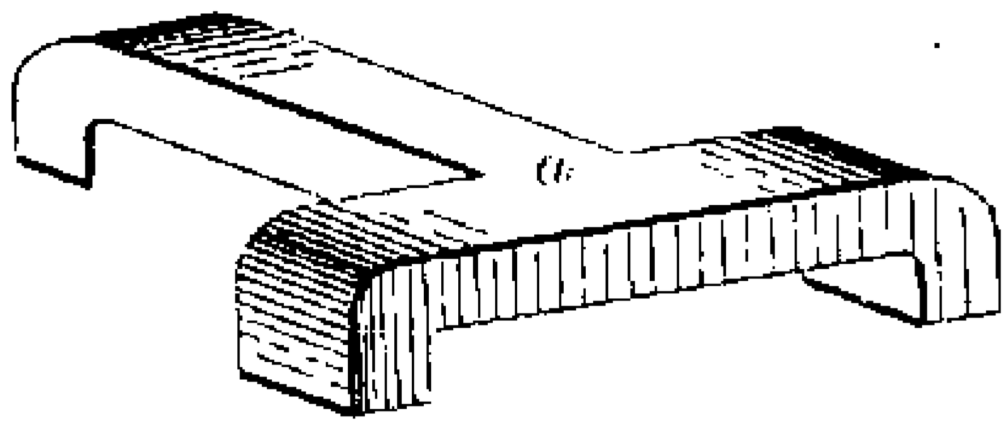


FIG. 155*b*

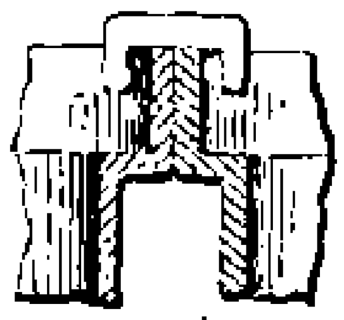


FIG. 156

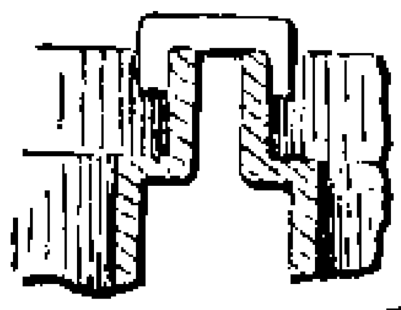


FIG. 157

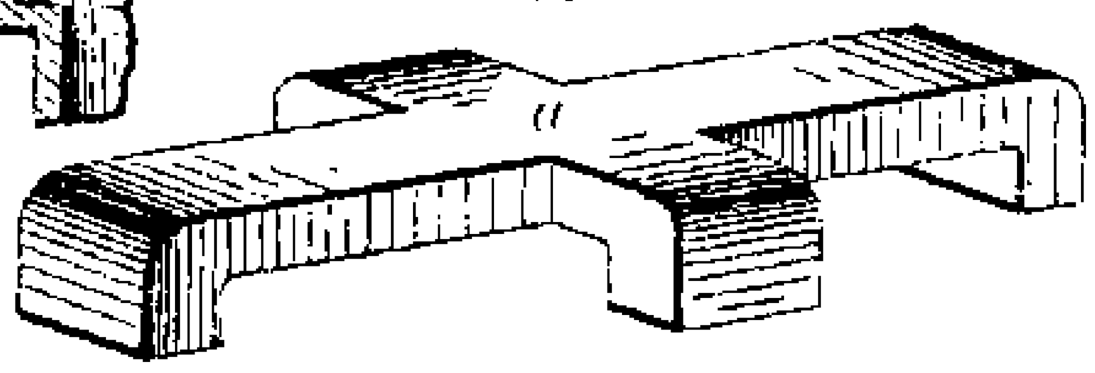


FIG. 155*c*

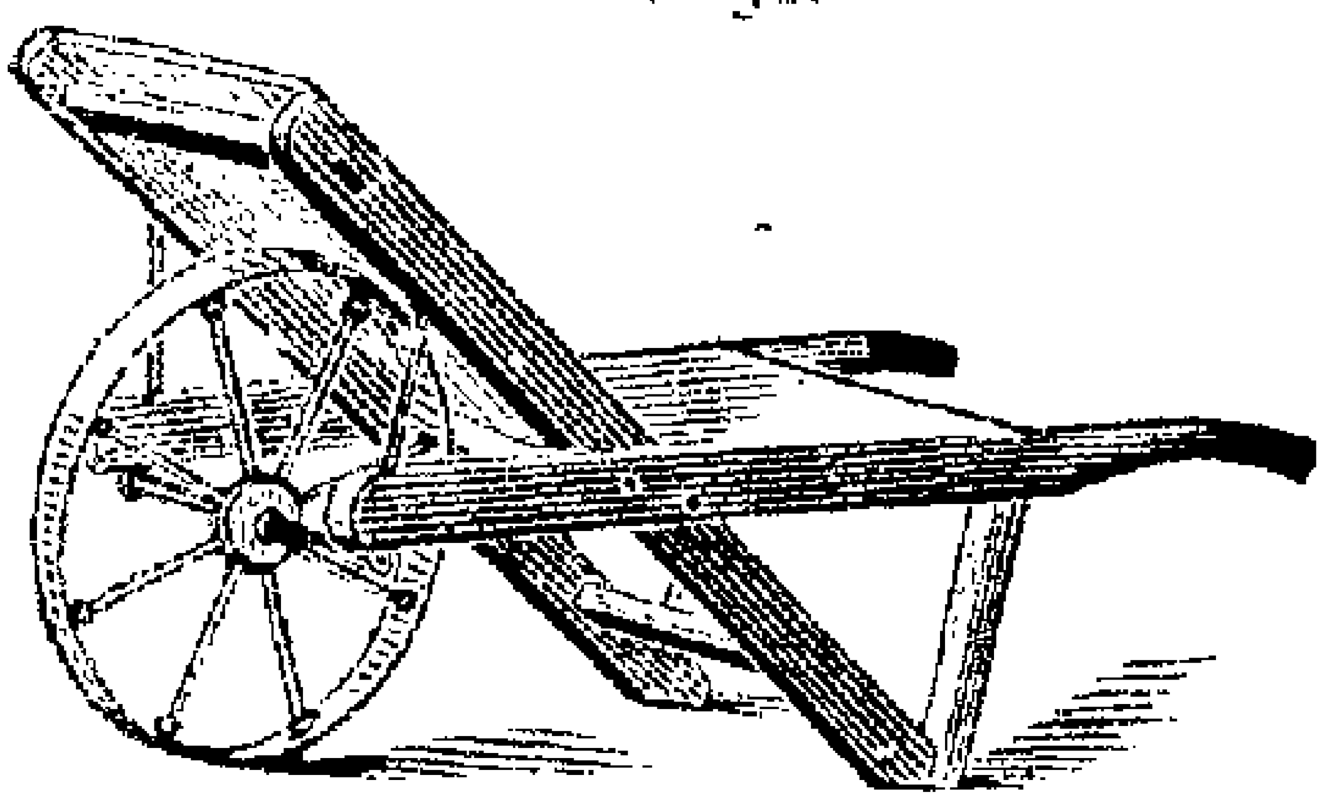
Figs. 156 and 157 illustrate the relation of the pipes and binders before and after burning.

The binders *a* are formed of the clay used in making the pipe, or of other suitable clay, with a body-piece, from which project two or more legs, as shown in Figs. 155*a*, 155*b* and 155*c*, and then burned in a proper kiln, with the pipes. When thus made they are hard, and although brittle, like other crockery or pottery ware, are yet abundantly strong for the purpose. One set of them can be used from twenty to thirty times before they become too much vitrified.

In filling the kiln the unburned pipes are placed in the usual way, but the pipes in the upper tier are connected each with

its neighbors by these binders, as illustrated in Figs. 153 and 154, where *A* represents the pipes, and *a* the binders. This makes the upper layer of pipes one compact mass, and does away with all danger of their getting out of place in burning, thereby preventing them from becoming bent or adhering together in masses. Binders a' are used to connect the tier of pipes with the wall of the kiln, special brick a^2 being built into the wall to engage with the end of the binders.

FIG. 158.



The pipes shrink in burning, so that the binders should fit loosely when the kiln is set, as shown in Fig. 156. Fig. 157 shows the position of the pipes after they are burned.

The barrow shown in Fig. 158 is intended for wheeling sewer-pipe and drain-pipe, and it is built very substantially, the wheel being of iron, and the remainder, with the exception of the back braces, being of wood.

TABLE SHOWING DIAMETER AND THICKNESS AND AVERAGE WEIGHT PER FOOT OF SALT-GLAZED VITRIFIED SEWER-PIPE, USUALLY KEPT IN STOCK BY MANUFACTURERS.

Diameter of pipe.	Thickness of pipe.	Weight of pipe per foot.
3	1/2 inch	6 pounds.
4	1/2 "	9 "
5	5/8 "	13 "
6	3/4 "	16 "
8	3/4 "	21 "
10	7/8 "	32 "
12	7/8 "	42 "
14	1 "	50 "
15	1 1/8 "	56 "
16	1 1/8 "	64 "
18	1 1/4 "	74 "
20	1 1/4 "	86 "
22	1 3/8 "	98 "
24	1 1/2 "	110 "
30	1 7/8 "	160 "

Double-strength pipe usually costs about 30 per cent. additional to that of ordinary strength.

Many manufacturers furnish pipe and branches only in two-foot lengths, and furnish additional lengths only to special order.

CAPACITY OF SEWER-PIPES FOR RESISTING PRESSURE.

The best grades of salt-glazed vitrified sewer-pipes will stand an inside pressure of 100 to 140 pounds per square inch, according to diameter of pipe.

They will stand an outside pressure of 14,000 to 40,000 pounds per square inch, before cracking or crushing, according to diameter of pipe.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by 0.434. Approximately, every foot elevation is is equal to ½ lb. pressure per square inch; this allows for ordinary friction.

A "miner's inch" of water is the quantity discharged through a hole one inch square, six inches below the surface of the water, measuring from the top of the opening, and is approximately equal to 12 U. S. gallons per minute.

Pressure per square inch of columns of water: 25 ft. head, 10.82 lbs.; 50 ft. head, 21.65 lbs.; 100 ft. head, 43.30 lbs.; 150 ft. head, 64.85 lbs.; 200 ft. head, 86.60 lbs.; 250 ft. head, 108.25 lbs.; 300 ft. head, 129.90 lbs.

Doubling the diameter of a pipe increases its capacity four times. Friction of liquids in pipes increases as the square of the velocity.

When salt-glazed vitrified pipes of clay are used for water conduits, extra long sockets should be formed upon the pipes for the purpose of making a strong joint, capable of resisting the desired pressure.

The drain-pipe for sewerage purposes now employed in this country and in Europe is in various shapes, but the circular form is the one in most general use.

CHAPTER XIII.

THE MANUFACTURE OF DRAIN TILE.

DRAIN TILE for agricultural underground drains are usually circular, and measure from 2½ in. to 12 in. in diameter and one foot in length. The following table gives the prices as F. O. B., at factory say in central Ohio, no allowance being made for breakage:

DRAIN TILE—IN ONE FOOT LENGTHS.

Inside Diameter.	PRICE.	Branches each.	Weight per foot.
2½ in.	$12.00 per 1,000 feet	7 c.	3 lbs.
3 "	15.00 " " "	8 c.	4 lbs.
4 "	22.00 " " "	10 c.	6 lbs.
5 "	30.00 " " "	12 c.	8 lbs.
6 "	44.00 " " "	15 c.	12 lbs.
8 "	80.00 " " "	25 c.	18 lbs.
10 "	120.00 " " "	40 c.	28 lbs.
12 "	150.00 " " "	60 c.	42 lbs.

Over 12 in. in diameter the tile are usually 24 in. long.

They can be made of about the same kind of sandy clay as bricks, and are burned sufficiently to include as much porosity and toughness as possible.

There is no reason why tiles of this kind cannot be produced cheaply in almost any neighborhood.

Clay used for the manufacture of building brick will make good drain-tile, care being observed, however, not to have the clay too sandy, as tile made from such clays would be too weak to stand distant shipment. In mining the clay from the bank it should be thoroughly mixed from the top to the bot-

tom of the clay bank, and some clays when thus mined and mixed give good results when the clay is taken directly from the bank. Some clays require to be dug in the autumn or winter and exposed to the frost, while others may be spaded up and exposed to the action of the air for a longer or shorter time with beneficial results. Clays of all characters used in the manufacture of drain-tiles will be more or less improved by being run through a pulverizer. It is only through practical test that the best clay can be selected for the manufacture of drain-tile, as it is impossible to foretell the various peculiarities which will be developed in drying and burning various clays. One rule, however, may be laid down, that is that an open, coarse, gritty, sandy, non-plastic clay will not make good drain-tile. The clay used for this purpose should be plastic, smooth to the touch, and possessing such characteristics as would commend it for the manufacture of a good grade of building brick. Any clay selected for the purpose should possess the quality of drying in the open air without damage.

PREPARING AND HANDLING CLAY FOR TILE.*

Build the factory near the clay—it is better for the farmers to haul the tile a long distance than for the maker of tile to haul the clay. With the factory located, and the capital small and the demand for tile likely to be limited, purchase a horse-power tile mill, erect a round-crowned kiln 17 feet in diameter or a 12x15 ft. crowned kiln 10 feet high, erect sheds and purchase trucks. The capacity with five men is a kiln a week—it must not be less. System is necessary to success, hence systematize the work as follows: Monday, empty and fill the kiln and fire in the evening. Tuesday, clean the sheds and make tile, continuing through Wednesday and Thursday. Friday, haul clay with two carts, strip off the top soil and mix the spadings of clay well in the pit. The temperer remains in the pit, levels each load, and adds to each spading the necessary

*Read by Mr. John G. Wagner, of Covington, Ky., before the Ohio Tile and Drainage Association, February 14, 1888.

amount of water. The clay-temperer should not use a hose or let the water run on the clay. The man who tempers the clay should have good judgment and quick discernment. The interested eye of the owner must supply the missing link here as well as elsewhere. On Saturday haul the wood or coal and make every provision for an early start on Monday.

After a few successful years, if accumulated capital and the demand for tile justify in enlarging the works, purchase a larger machine, put in steam-power, erect another kiln of the size above given. A kiln that can be emptied and filled in a day is the best. More kilns rather than larger ones should be the rule.

After the works have been enlarged it is preferable to employ a different method of getting in the clay. Construct an iron (T-rail) track, use side dumping-cars and a ⅞ wire rope. With these appliances a man and a mule can haul clay sufficient to keep the machine running. Divide the pit into two parts, each part holding a kiln of tile, fill and temper one side, and while it is being used fill and temper the other. If the clay can be allowed to stand a day or so in the pit after being tempered, it works better. The engineer, who is close by, has ample time to level and sprinkle the clay as it is dumped in the pit. Have near by a forty-barrel tank of water, filled with a jet pump. This tank is a valuable adjunct to the factory. Attach a hose to the tank in sprinkling the clay.

In early spring the clay comes from the bank sufficiently moist. To preserve this state of moisture cover the bank with a few loads of straw, which saves much hard spading and objectionable clods. It is not best to use clay direct from the bank, so pass it through the tempering pits. The handling and the action of the air improve the working of the clay. With steam power it is best to use a good crusher.

No rules will enable every tile or brickmaker to prepare the clay aright. He must learn thoroughly the nature of his clay and how to manipulate it.

Most clays are benefited by wintering, but this is expensive;

yet with some clays it is money saved to spade them and let them weather through the winter.

Strong clays which crack badly are benefited by mixing with them the dust of crushed bits of brick and tile, or by adding sand, or if these are not to be had, use saw-dust or coal-dust. The tile will be weaker where saw-dust or coal-dust is used, but strong enough probably for all practical purposes.

Those having much trouble with their clays can learn useful lessons from sewer-pipe and pottery manufacturers. A visit to Trenton, N. J., or East Liverpool, or Akron, O., may be a profitable investment of time and money, in seeing how the manufacturers at those points work their clays.

DRAIN TILE: ITS MANUFACTURE AND USE.*

The subject assigned me may be considered by some as foreign to the line of thought laid out by the convention proper, but as many of us are acting in a dual capacity, tile makers and brickmakers, and to others perhaps who do not fully know the use of drain tile, an idea might be dropped that would engender new thought which would be beneficial.

Drain tile, which is absorbing at the present time a large amount of labor and capital, especially in the Western states, had its origin most marked in the first century of the Christian era. Calumella, a Roman contemporary with the philosopher Seneca, in the reign of Nero, treats at length and with fullness, not inelegantly, of the cultivation of all kinds of grain, garden vegetables, trees, the vine, olive and other fruits. He gives directions for selecting farms, the management of servants and slaves. He himself lived in Rome most of the time, but owned a small villa and farm in the country. He advanced the idea of loosening the soil in various ways—by cultivation, and to quote his words, he says, "For to cultivate is no other thing but to loosen and ferment the earth; therefore the same land which is both fat and loose and crumbling yields the greatest

* From a paper by E. M. Pike, Esq., of Chenoa, Ill., read January 22, 1891, at the Fifth Annual Convention of the National Brick Manufacturers' Association.

profit, because at the time it yields the most it requires the least." He speaks of the different kinds of soil, whether it be woody, stony or marshy land, covered with rushes, fern plants or shrubs.

He says if it be wet let the abundance of moisture be first drained or dried up by ditches—of these we have known two kinds, blind and open. Then he describes the manner in which the blind ditches were made with stone and clean gravel, but if these were not obtainable to make bundles of brush tied together, on which were laid boughs, over which the earth was thrown, leaving the ends open for the free passage of water both in and out. Thus we can see that they had some knowledge of the benefit of under-drainage as far back as the beginning of the Christian era, and I have helped make the same kind of a ditch in Maine, my native state, in my boyhood days, and it worked well. We have no knowledge that the Romans used drain tile for draining land, but the same author speaks of the use of earthen pipe to convey water to cisterns as follows: "But if these also fail you, and the small hopes of spring water force you, let large cisterns be built for men, and ponds for cattle, for gathering and keeping rain water, which is most proper and suitable for the health of the body, and this you may have exceedingly good if you convey it in earthen pipes into a covered cistern."

I infer from the foregoing that earthen pipes were on the market, and doubtless cheap, for we have no information that would lead us to believe that the tariff was heavy on these pipes, or that strikes were frequent. So far as we know this is the oldest reference to under-drains for agricultural purposes. There is plenty of evidence that stone, which was common to the country, and brick also, were used in construction of sewers in cities centuries before the time of Columella, and perhaps earthen pipes may have been used for the same purpose; but we have knowledge of the making of brick with and without straw as far back as the tower of Babel, over 4,000 years ago, and this, allow me to suggest, was the first strike that ever occurred on a building or a brick yard.

Drain tile at the present time are usually made round, one foot in length and of all sizes from three to eighteen inches inclusive.

In the past, not many years ago, they were made horse-shoe shaped, with and without bottoms, also V-shaped with the open side down, and perhaps other shapes, but at present the round tile for convenience of manufacture and use supersedes all other shapes. They are manufactured by machinery made in this country, which is unsurpassed; moulded and dried on slatted floors or shelves and usually burned in close kilns, after which they are ready for use.

The benefit derived from drain tile scarcely any one disputes, for we have learned that they are not only beneficial to drain the water away, but also beneficial in time of drought. The benefits arising from tile drainage are many. It lengthens the seasons at both ends. It enables the seed to go into the ground earlier in the spring, makes it grow faster during the summer, and matures the crop earlier in autumn. Franklin said, "Burn a candle at both ends and it is soon gone." A season that is ushered in amid the cold wet days of May and closed by early frosts of September is too short for successful farming. The draining obviates this by draining and warming the soil; it being more mellow and open to the circulation of the air, will thaw out earlier in the spring.

We who have lived in snowy countries have observed that the culverts under the roadways and the banks of ravines and the hill-sides were the first to get bare in the spring, and thus drainage warms the soil. Actual experience has shown us that drained soil is about ten degrees warmer eight inches below the surface than undrained soil at the same depth. Heat is necessary to the germination of seeds and growth of plants, whether the tiny flower of the hot-house or the expansive fields of corn on the western prairie, and the seed that will thrive in warm underdrain soil will rot in cold damp soil, so that oftentimes the few degrees of heat betters the condition of the seed into life and growth, and plant life is hastened by the same

helping causes, and consequently larger crops, earlier matured, of better quality result than on cold undrained soil. We can also see that the same order of things would bring the harvest earlier, and therefore less liable to the early frosts of autumn.

We have said that drainage is beneficial in dry weather. The rainfall percolates through the earth to the tile, some three feet below the surface. creating innumerable pores. In dry weather these same pores, opened by action of the water, become breathing holes, all centering on the tile. These openings create a draft through the tile, which brings the night air laden with moisture that comes in contact with the soil, which is cooler, and the dampness is thus taken up. The earth virtually breathes—exhales water in wet seasons and inhales moisture-laden air in dry seasons, thus showing tile drainage to be a safeguard against drouth as well as over-abundance of water.

"White man brings rain," says the Indian. He brings it by cultivating the soil and covering it with verdure; but this same white man has become wise enough to drain away what he does not want.

A few years ago quite a commotion was raised, and on first thought too that the tile makers were ruining this country by draining the water away and destroying evaporation, and this theory was substantiated by professors in agricultural colleges and others, also that tile draininge was conducive to floods; but after due investigation, just the reverse are the facts. Tile drainage throws the water level lower, stores it for a time in the earth, prevents surface wash and too much rapid evaporation; the earth becomes spongy and loose and easily cultivated.

If we look back over the history of this country we shall find far longer drouths many years previous to the laying of any tile.

It might be of interest to those present to know to what an extent this enterprise has been carried on in the western states. Illinois, for instance, has about 800 factories, and from best statistics obtainable, have made and laid about 200,000 miles, or enough, if laid continuously, to belt the earth eight times;

this reduced to rods makes 64,000,000; calculating the laying of this tile at thirty cents, and the cost of them twenty-five cents per rod, which is a fair average in Illinois, would make the sum of $35,200,000. There are larger estimates than this. To those not knowing the value of drain tile this might seem an extravagant expenditure of money, but allow me to say that no money is so well expended as that judiciously expended in tile.

Illinois is not alone in this great enterprise. Indiana and Ohio are close behind, while Iowa, Kansas, Missouri and Michigan are fast falling into line, and our friends of the South have been watching us in this enterprise, and they too have gone into the business.

There are other benefits outside of agriculture. Take all this vast amount of drainage in a sanitary point of view, we can imagine, and imagine only, its benefits.

In earlier years fever and ague, or the shakes in common parlance, were as common as sunny days; but tile drainage has carried away the shakes by draining out the miasmatic ponds. The frogs and the mosquitoes too have gone, but the shakes have left their foot-prints on the brows of many hairless-headed men, of which you have a specimen before you.

The advantages of the use of tile are manifest on every hand, with these millions of capital invested and thousands of men employed. It has stimulated mining and transportation, and given new impetus to local trade in hundreds of towns and villages in states where factories are established, also business to manufacturers of machinery, and labor to mechanics of other states. From the standpoint of to-day the future looks bright to the farmers, and so it does to all, whether they work with brain or brawn.

Clay is a theme as broad as the world and deep as the earth, universal in all climes and countries. Clays are of many kinds, composed of many elements, and we, as clay manipulators, analyze them practically rather than theoretically, for by practice only can we know how to handle our own clay. If we tried theory rather than practice, it would be like book-farming, it would run to theory and the corn would run to weeds.

This great system of farm drainage which is taking the country both north and south, is creating capital by the millions, which will be spent largely in building and beautifying homes for the people; and we, as brickmakers, are already called upon to tear down and build greater manufactories in order to supply the present and coming demands. Our country is becoming more favorable to human existence, wet lands, bogs and miasmatic swamps are giving place to dry and arable fields, and the influence is felt by countless thousands who breathe pure air and enjoy the sanitary benefits as a consequence, and yet this work is only begun. Emerson says, "Tiles are political economists, so many young Americans announcing a better era and a day of fat things." Older Americans are also announcing a better era, and the more tiles they use the more fat things they will have.

These annual associations are conducive of much good. We meet for our mutual benefit and to advance our mutual interests. Our vocation is a noble one; we add wealth and happiness not only to the present, but to generations yet unborn. The products of our toil in shape of burned clay will stand after we have passed into the great beyond. We build better than we know.

Every clay worker knows the lamentable lack of available knowledge pertaining to the clay business. In our business every one has had to work out his own problem and to overcome his own difficulty by his own experience. All know the cost of this in time, money and mental anxiety. The policy a hundred years ago of potters was to keep secret all they knew and not let others profit by their experience. At the Royal potteries in England neither king nor subject could enter those secret workshops, the workmen themselves being sworn to secrecy. But in our day of "reciprocity" and reciprocal knowledge, we are above that; we have discovered that individual progress in our calling is very much due to interchange of individual experience.

Life is too short for each one of us to learn by long and hard

experience that which can be told us by another who has gone through it. We clay workers have enough to do to uncover the unseen, which is constantly rising before us in the shape of costly experience, and should aid each other in cutting corners to success, and then gain time for fitting foundations for the palaces of brick yet to be built by the craft, either with or without straw, whether hard, soft or salmon, glazed or re-pressed. Strikes and walking delegates will only be known in history.

ELEVATING DEVICES FOR BRICK AND TILE.

Fig. 159 illustrates an endless elevator, with swinging shelves, in position to carry drain-tile to two upper floors.

Platform elevators are also used to do the same work. The platform is generally made 8x4 feet, so that a man and loaded truck can be lifted at once. Both of these forms of elevators are furnished by the Frey-Sheckler Co.

DRYING DRAIN-TILE.

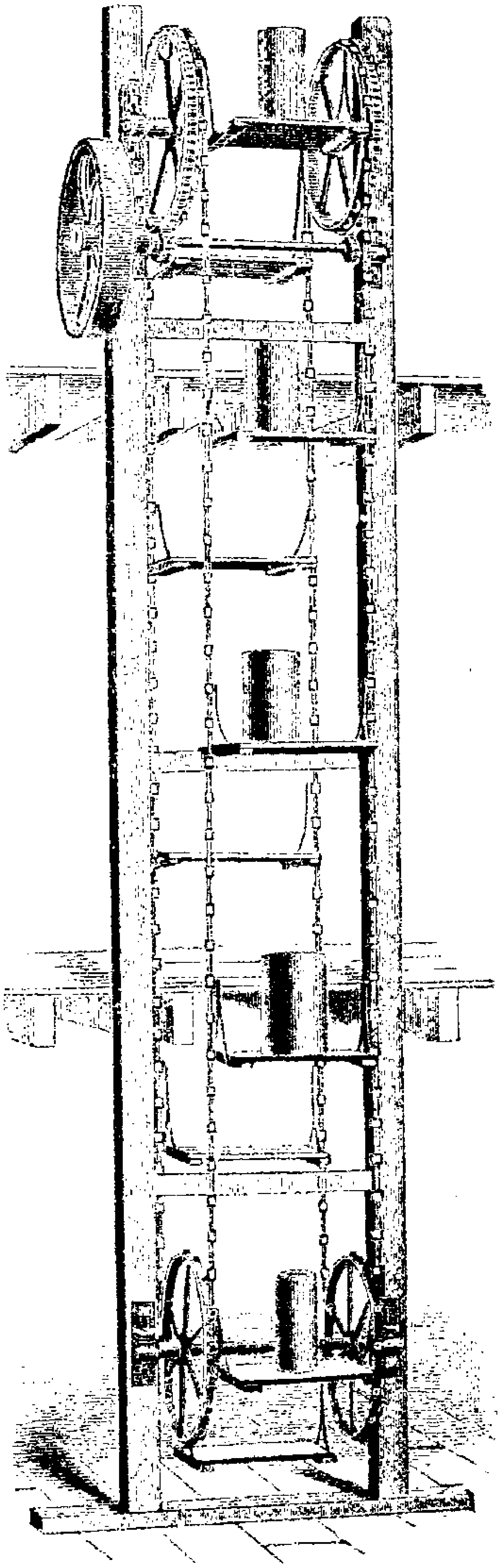
Different clays require different methods of drying, for, while some tile-clays are so tough as not to dry properly in the sun, others are so tender that it is difficult to dry them in the air. It is the lack of uniformity and the employment of too high a temperature at first in drying, and not the after rapidity with which the tile are dried, which usually causes the tile to crack. The drying of the surface too rapidly will crack the green tile, for the reason that the centre of the tile is raw, and does not shrink as rapidly as the surface.

Many manufacturers of tile could not succeed very well without steam-drying, especially in the early and latter part of the season. One tile-maker, whom I now recall, used 6800 feet of one-inch steam pipe in a shed 30 by 120 feet, two stories in height, and he made and marketed 18 kilns of tile one season before the other factories in his neighborhood began operations.

The Wolff, and similar forms of dryers, will dry ordinary tile in 24 hours without cracking the ware.

When the tile are green the temperature in the dryer, or shed, should not exceed 70° F. When the tile are dry enough

FIG. 159.



to turn, increase the temperature as the tile will stand it, so that when the tile are about dry the thermometer will indicate 150° F.

DRYING IN OPEN SHEDS.

Drain-tile are usually dried in sheds more or less open in their construction, having doors so arranged at the sides of the shed as to allow the admission of air into the drying apartments in such quantity as may be needed, and as the nature of the clay may require.

BURNING DRAIN-TILE.

In the burning of drain-tile, as in the burning of sewer-pipe, it is essential that the tile should be thoroughly dry; the drier the tile the better the success to be attained. The time, fuel, and other items of cost, which have to be expended for the thorough drying of the tile in the kiln, might just as well be saved, if possible, by utilizing the natural method of drying. The manner of setting the tile in the kiln is also an imporant item, and the method employed varies with the various kilns in use. When the Dutch or open-top kiln is employed, it is usual to set the small tile in the bottom of the kiln; the larger tile is then placed in the central tier, the smallest tile being placed in the upper portion of the kiln, and in no case should the tile be allowed to come in contact with the walls; a space of about one inch and a half should be left open all around the side of the kiln. When the up-draft or crown-top kilns are employed for burning drain-tiles, the method of setting is similar to that which has just been described, although it is found from experience that better results are obtained if the tile of the largest diameter are set near the top. When the down-draft kiln is used for burning the drain-tile, it is desirable that the large tile should be set at the top, care being observed, however, not to place the larger tile at the points of extreme heat. And in kilns of this character it is desirable that, if there are any tiles which are not thoroughly dry, they should be set at the bottom of the kiln, so as to obviate the necessity of driving the water-smoke from the damp tile through those which are dry.

The method of nesting the tile varies with different clays; some clays will allow close nesting, while other clays require to to be nested very openly. No rule for nesting the tile can be laid down; the best method to be employed can be developed only from thorough knowledge of the practical qualities of the clay to be burned. In order to avoid the cracking and loss from improper nesting, it is desirable that, where defects of this character occur, the cause should be thoroughly investigated and a memorandum made of the result upon the books at the works. If some such simple system as this could be adopted in the various clay-works of the country, and the result of the practical experiences could be brought out at the conventions, or recorded in the pages of the journals devoted to the clay industry, great good would result to the trade in many of its branches.

In firing the tile care should be observed not to push the burning too rapidly; only a light fire should at first be used in the fire-box; then the heat should be raised very gradually, fuel being added in smallest quantities, as nothing is to be gained from pushing the burning of the tile in its early stages. The water-smoke must be driven off gradually, but surely, until at last none of it can be discerned mixed with the blue-black smoke which issues from the top of the flues or stack. Patience worketh wonders in burning drain-tile, as in burning all other classes of clay products. Of course the drier the tile the quicker the kiln may be burned off; but, as it is not possible to have all of the tile of a uniform degree of dryness, all the dry tile have to be held back until the moisture has been thoroughly driven from the damp tiles, otherwise crushing, cracking, and other losses will result. Even after the water-smoke has been thoroughly driven off, it is desirable not to push the burning too rapidly; gradually increase the heat until the tile have been brought to nearly the melting-point, and at this temperature the heat should be maintained for two or three hours; great caution, however, should be observed not to increase the heat to the actual fluxing point, for in such a case

the tile would run together and the kiln prove a loss. With some clays, however, it will be necessary to maintain the final heat all the way from four to eight hours. The kiln, when burned off, should remain closed for about twenty to twenty-four hours, after which time it may be gradually opened and allowed to cool.

The proper management of open-top kilns, especially in burning drain-tile, is discussed in a practical manner in the January (1889) number of the Drainage Journal as follows:

"While it is true that open-top kilns are not generally in good favor among our leading tile manufacturers, it is also true that there are quite a number of them in use. They are not the best kilns, but they serve a good purpose oftentimes, where the burner knows how to burn in them. Indeed, we know some who burn excellent tile in open-top kilns. The suggestions that we make have a practical side in our judgment that will apply to other kilns in some respects. They are briefly as follows: Set the tile a little open in the corners and at points where the difficulty of getting a draft of heat is experienced. Make the openings over the heat flues larger at such points so as to allow the heat a freer passage, and closer at the points where it has been inclined to draw heretofore. In bringing the kiln to a red heat after the water-smoke is off, keep the spots that have been inclined not to burn well in advance of other portions of the kiln. It is pretty well known to burners that the hot places tend to get hotter. It will be well to keep the side arches where the tile have not burned well heretofore, in advance in the heating to water-smoke. The general firing of the kiln after the red-heat point has been reached should look sharply to the points suggested. Where there is a tendency in one portion of the kiln to fall behind, the burner may increase the heat in the better fuel used, or by using a fuel that will send a flame up through the ware, and thus increase the draft of heat at the point desired. After a high heat has been reached in the kiln, except at such points as are inclined to lag, it is the practice of some, in the use of open-top kilns, to open the

platting in the centre of the cooler spots, and set three or four large tile on top of each other, setting them in the opening in the platting. The tile serves as a flue to increase the draft and draw the heat through the cold spots. Others cover the hot spots of the kiln tight, and in this way drive the heat where it is wanted, which may be done by covering with sheet-iron, and afterwards throwing three or four inches of dirt on the iron. By tight planting in the way suggested, the heat can be taken to the sides, or to the centre, or to the centre and sides, as may be desired.

"Again, we call attention to the heat-flues. They may not be large enough or open enough on top, or too open; also the setting of the ware of any kind will have much to do with the result in burning. The burner should be a man of good practical common sense, quick to observe what is going on, and always ready to apply the necessary means 'to get there,' as the boys say. "Talent may know why this and that should be done, but it is 'tact' that knows how, seizes the opportunity and does it. The 'tact' men are in demand for burners. They make all kinds of kilns go."

BURNING DRAIN-TILE WITH NATURAL GAS.

The burning of drain-tile with natural gas is about the same as the process of burning with wood or coal, the main difference being in the proper regulation of the draft, and the draft required to obtain the best results can only be learned by trial. A round down-draft kiln, 20 feet in diameter, set 13 high in the centre, is the style of kiln which we shall select for describing the process. If connected by a two-inch main with the natural gas well at a distance of from one to two miles, the pipe will supply enough gas to burn two kilns, run the engine, and heat the dry shed and dwelling, with 40 pounds pressure.

If the kiln is not given draft enough, the tile will not be burned sufficiently; if only a little more draft be given than is usual with wood or coal fuel, the fire boxes are liable to be melted down, and the top tile will be too hard and out of shape,

while the bottom tile will be too soft. By increasing the draft, and holding the heat longer than with either coal or wood, good results will be obtained. The tile can be dried in less time than with wood or coal; but with natural gas the firing should continue about twelve hours longer. With wood the kilns could be finished in twelve hours after the red heat is uniform through the kiln; but with natural gas, hold it 24 to 30 hours.

While driving off the water-smoke it is necessary to give the kiln but little attention. Fire the kiln in the evening, turning on what gas the tile will stand, and do not visit it any more until next morning, when turn on more gas, and at noon increase the fires, so that by night the water-smoke is mostly off; then the fires should be increased so that by midnight the fire-boxes, if the clay will allow, should be as hot as they will admit of being without dropping the arches. From this time on, visit the kiln every hour or so to see that none of the fire-boxes get too high a heat. When the heat is well through the kiln, begin to slacken the fires, so that the top tile may not get too much heat before the bottom gets enough.

TILE-MAKING MACHINES.

Fig. 160 shows the Improved Centennial Machine, made by the Frey-Sheckler Co. One of many valuable features of this machine is its great pugging capacity. It is provided with two shafts, which revolve in opposite directions, one running at a speed five times faster than the other.

It is adapted for the production of Drain Tile, Fire Proofing, Terra-Cotta, Lumber, Building and Fire Brick.

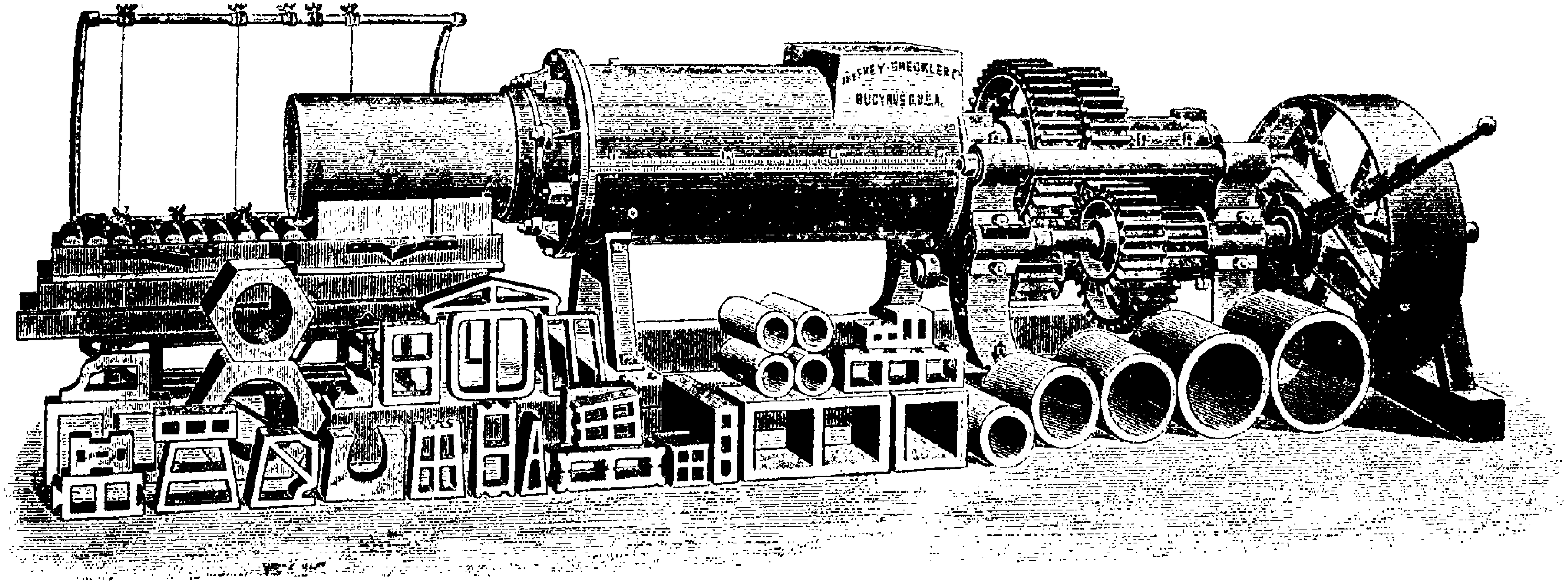
This cut shows the Improved Centennial in connection with the Combination Table arranged for making Drain Tile and Hollow Blocks.

This machine will make drain tile as large as 20 inch diameter.

The cut also shows a variety of work made on this machine.

The Combination Table, which is shown in connection with

Fig. 160.



THE IMPROVED CENTENNIAL ARRANGED FOR TILE.

the Improved Centennial Machine, is especially adapted for cutting Tile, Hollow Building Blocks, Fire Proofing, Terra-Cotta Lumber, etc. The cutting wires can be easily shifted, so as to cut the various lengths required. Suitable straight rollers are furnished for brick and hollow blocks, while those of tile have depressions in them for one, two or three streams of tile.

All sizes of tile, up to and including 5 inches in diameter, are cut and handled on the rollers; from 6 inches to 10 inches in diameter are cut and handled in copper-lined or wooden troughs, that are made to fit the table.

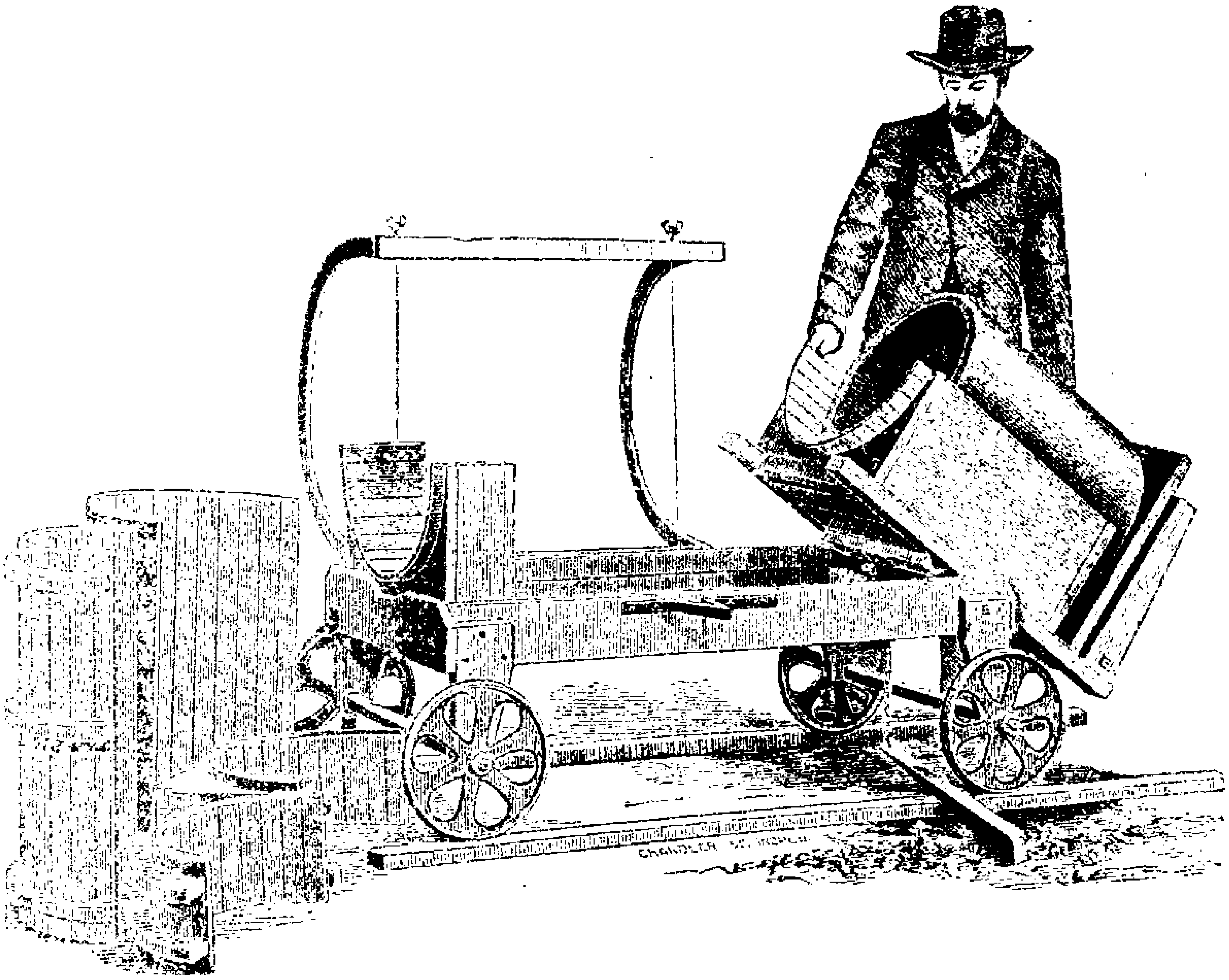
A suitable bed for the use of the Osman Patent Tile Carrier is also furnished with this Table, when desired, for tile larger than 7 inches in diameter. For large hollow blocks an additional cutting frame of suitable size can be attached in place of the small one. A screw adjustment raises and lowers the Table to any desired height.

The Machine and Table will occupy 16 feet by 4 feet 6 inches floor space. Weight of Machine and Table 4,225 pounds. Any of The Frey-Sheckler Cutting Tables can be used in connection with the Improved Centennial Machine.

Fig. 161 represents the Brose Patent Tile Table for cutting and handling Tile from 10 inches to 20 inches diameter, usually 24 inches long, made by the Frey-Sheckler Co. The mode of operating is as follows: After the large trough and guide, as shown by the cut, are thoroughly oiled the machine is started, when the tile runs through the guide into the trough, then the Table is released, so that it partakes of the motion of the tile, thereby securing a straight cut by means of the wires on the cutting frame. When cut, the table is tilted on the gudgeons, requiring very little effort, and the tile is thereby up-ended on a board which has been previously placed on the roller-frame on the end of the trough. This brings the end of the tile on the board near to the floor, where a two-wheeled truck, with two long prongs (which reach under the board), is used to carry the tile away to its place. As the large tile, when two feet long and twenty-five inches on the outside,

weigh nearly two hundred pounds, it will be seen that this mode and arrangement is needed to handle them. By a lever, the table is drawn back and held against the machine until

Fig. 161.

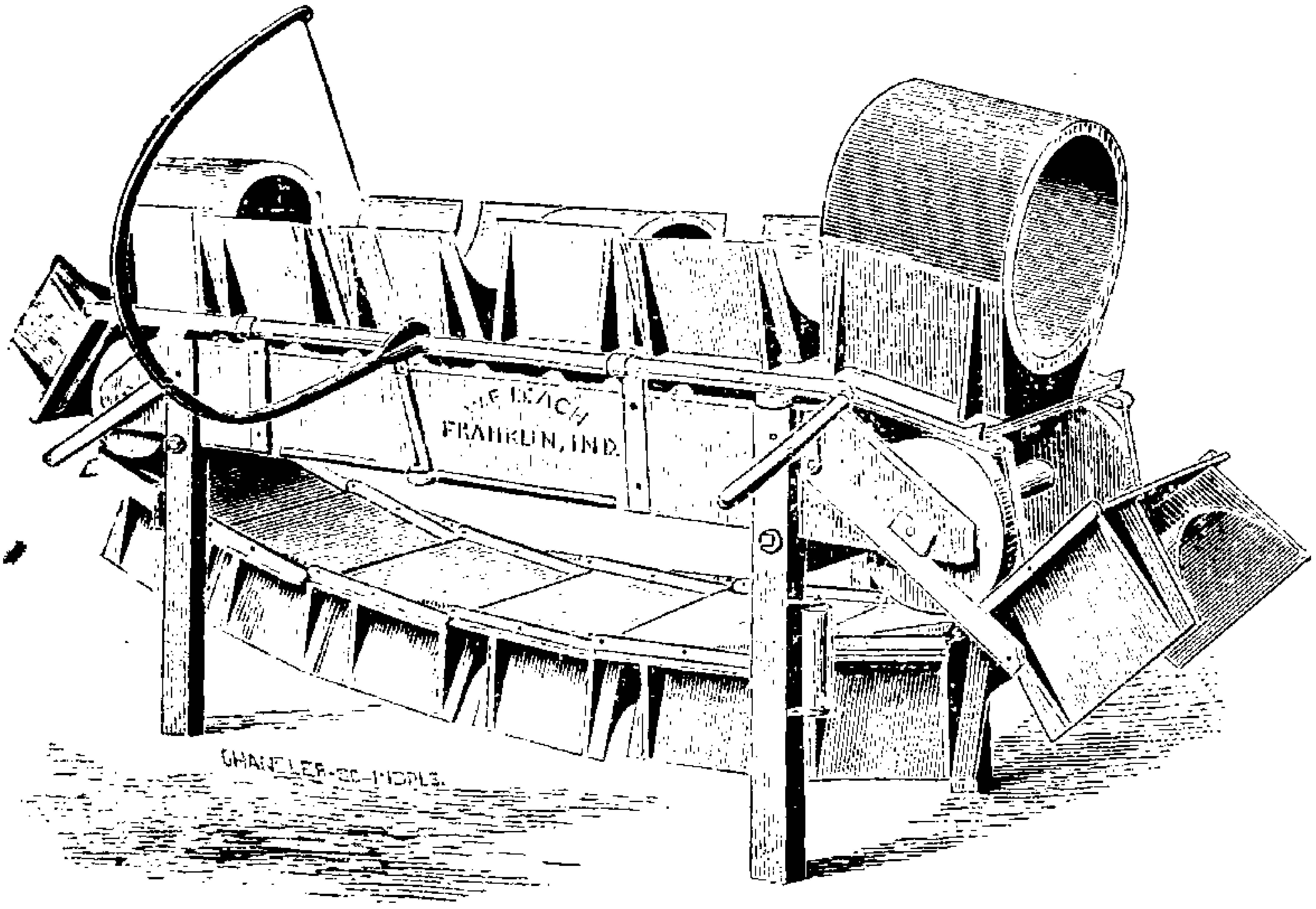


BROSE'S PATENT TILE TABLE.

ready to cut, the trough being held by a spring catch, which is released by the foot of the operator when the trough is tilted. Weight of Table, 160 pounds.

Fig. 162 represents the Leach Patent Table, also made by the Frey-Sheckler Co. This Table is intended for tile above four inches and as large as twelve inches in diameter. The troughs are self-adjusting, fitting the different sizes of round tile named. It will be noticed that all the receiving troughs, which are made of sheet metal, are hung together as a continuous chain so that the pipe as it emerges does not have to slide across the metal, but makes the trough follow along,

FIG. 162.



LEACH PATENT TILE TABLE.

fitting the next one to it in position for the tile. This Table works very nicely and will also dump the tile on a board if held in position at the end of the table. Weight, 170 pounds.

DODD'S CARRIER FOR HORIZONTAL TILE MACHINE.

The Dodd Carrier is shown in Figs. 163 to 165, and by its use tile of different diameters may be carried by the same set of supporting bars, instead of being compelled to change the bars for others having a concavity formed to suit the periphery of every different size of tile manufactured. This result is accomplished by forming the concavity in the carrier-bar upon as great a radius as the largest tile to be made upon the machine, and bridging the space between the ends of the bar with a strap of flexible material, upon which the tile is received.

Fig. 163 is a perspective view of a carrier complete, having its carrier-bars provided with flexible straps. Fig. 164 is a cross-section of a carrier showing the position assumed by the flexible strap when carrying a tile. Fig. 165 is a perspective

view of one of the bars and straps, with a section of the carrier-belt.

In constructing this machine the carrier-frame *A* is formed in the usual manner of two side pieces connected by cross-bars *a*, and supported upon short legs *b*, or by any other suitable means. Above the cross-bars *a*, which connect the two sides of the frame, is placed a series of rollers *c*, which support the endless carrier-belt or belts *B*. To this belt are secured by

FIG. 163.

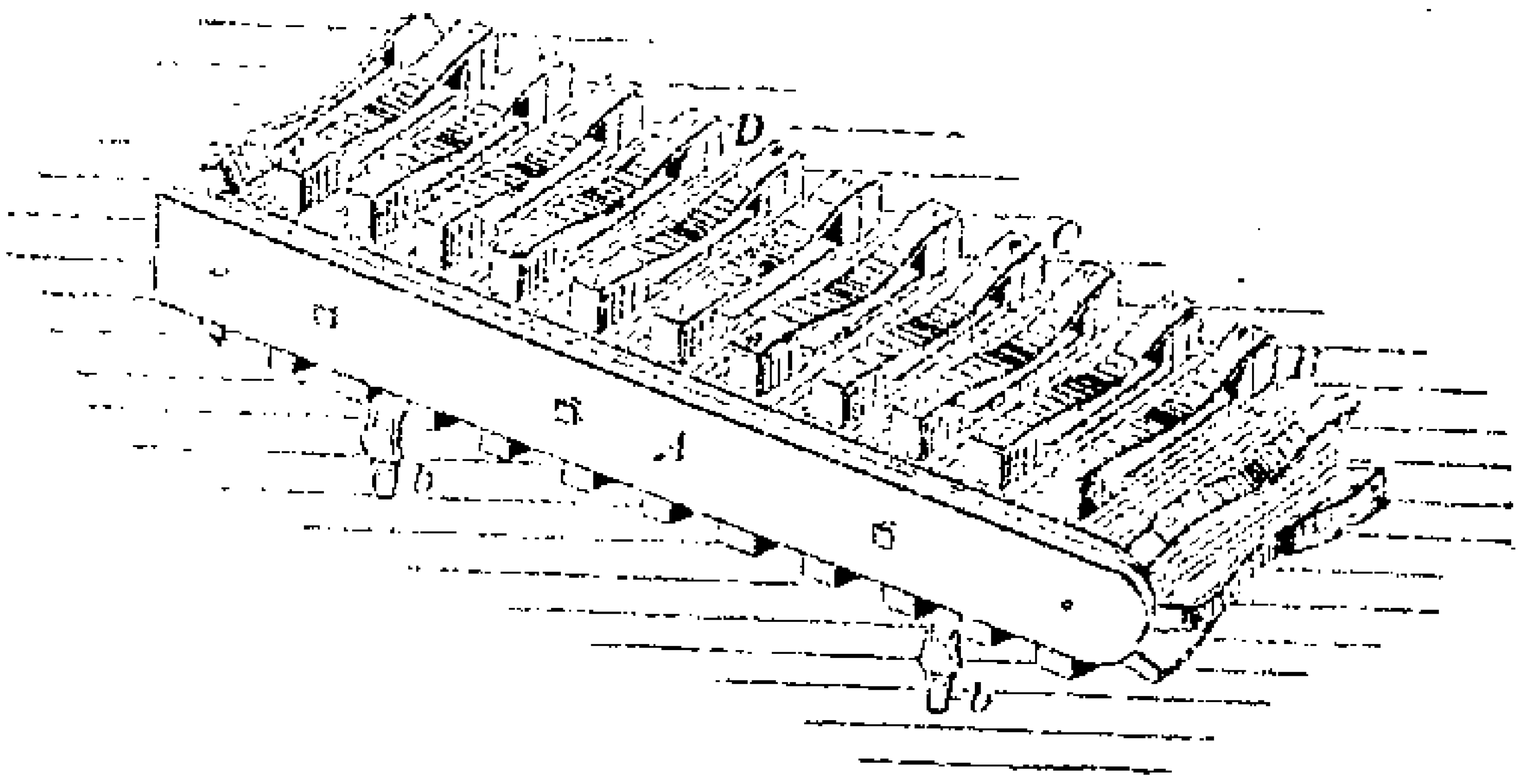
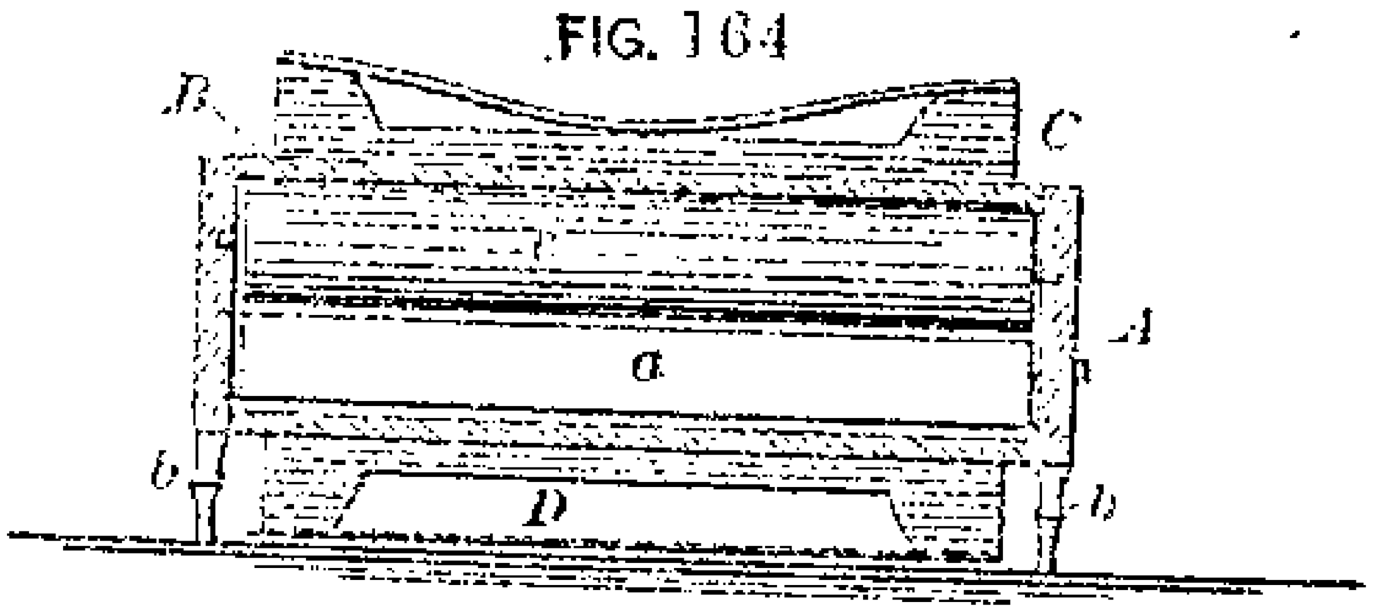


FIG. 164



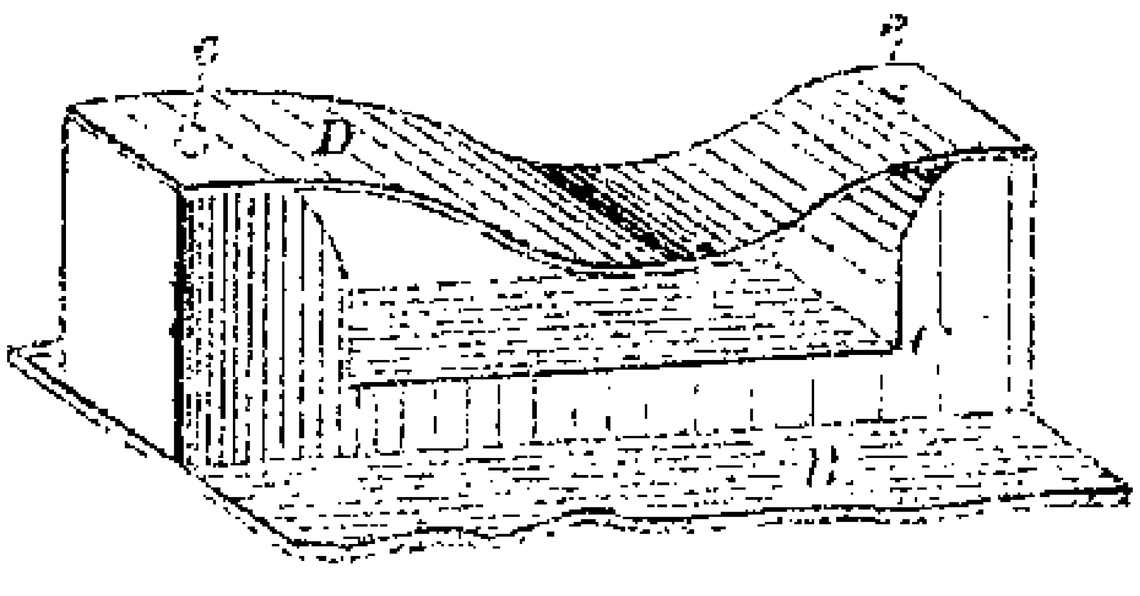


FIG. 165.

screws or other proper means the carrier-bars *C*. These bars have a cavity or hollow in the side opposite that which is attached to the carrier-belt, and bridging this cavity is the flexible strap *D*, secured at each end to the carrier-bars *C* by means of screws *e* or other proper fastening devices. These straps *D* may be formed of leather, rubber belting, canvas, or any other material possessing sufficient strength and flexibility,

it being necessary that they should give a firm support to the tile, and at the same time conform readily to its shape. In attaching the straps *D* to the carrier-bars it is preferable to allow the strap to drop or sag a little, as is clearly shown in Fig. 165 of the drawings, as it is thereby caused to conform more readily to the shape of the tile.

The frame provided with carrier-belt and carrier-bars having a concave receiving surface to receive the tile as it comes from the forming-dies is old, but the combination of the carrier-bars and a flexible bridging strap arranged to receive the tile as it issues from the forming-die is a new idea.

CHAPTER XIV.

THE MANUFACTURE OF ARCHITECTURAL TERRA-COTTA.

TERRA-COTTA is to-day the most available material used for the construction of buildings of all classes and forms. It is, in fact, the concrete part of them. It is, as well, indispensable in every assemblage of artistic architectural ornamentation and has virtually taken the place of stone, and is now used in the completion of seven-tenths of the structures erected. The use of terra-cotta dates prior to the time to which our histories reach—in fact, it is said, "that the children of Seth, the son of Adam, built two pillars, one of brick and one of stone, and they inscribed upon each of them the discoveries they made concerning the heavenly bodies, so that their inventions might be preserved to mankind and not be lost before they became sufficiently known." Brick was the building material of the antediluvian days. The word terra-cotta was then unknown, but after all it is but a refined baked clay, and some large stones must have been used in order to have models or inscriptions placed on them. In 1765 an old well was opened, accidentally, by some workmen at the Porta Latina, at Rome. In it were found Egyptian and Roman statues in terra-cotta, which were taken to England. Bas-reliefs were also exhumed at the same time. Among the features of Roman ceramic art are its metopes and historic friezes. The exquisite bas-reliefs of Luca della Robbia are known to all lovers of the beautiful.

Terra-cotta, a name in itself Italian, was first applied by Italians more to the purposes of ornamentation than of construction. The clay was plastic and easily treated.

Terra-cotta has great lasting qualities when made of the proper mixture of clays and when well fired. It will not vege-

tate as stone will, often causing decay. It is interesting to examine a piece of this material in cold weather under a magnifying glass. It will be found to contain almost infinitesimal icicles, but the strength of the composition is so great that it will withstand the natural expansion without injury. In beauty of color it has an advantage over stone, for by the use of chemicals almost any color can be produced, and they are found to be less apt to change under atmospheric influences. In terracotta we can find a scope for freedom, with a capability of supplying the increasing demand for decoration in the most durable material. The beauty of all things decorative should grow, and as terra-cotta is comparatively cheap, it has become an ornamental factor.

It is an interesting sight to stand in a studio of a modern terra-cotta factory and witness the work of the artists in this material, who with intelligence stand before large easels supporting masses of clay, carving bas-reliefs from sketches. Many of them seem to love their work. One often finds a small boy at his easel moulding some simple device. A model having been perfectly prepared, a piece mold is then taken of it in such manner as to allow of its being easily withdrawn without injury to the model. Much skill is required in making the plaster molds to fit the model; great practical knowledge and experience are required. Bungling in this is sure to prove fatal to the work, and men of superior ability are usually assigned the task. The clay is not forced in en masse, but deftly pressed against the sides of the mold. It is really impressive to see the transformation of this plastic material into a substance which is more imperishable than granite.

The modelers should possess great dignity of thought and imagination, and it has been suggested that the work should be given the artist's personal attention—in fact, that the molding of the model should be executed by his own hands, that it may not lose his individual conception of the subject and that in not doing the work the standard of artistic excellence is being rapidly lowered.

Terra-cotta is now used in every feature of decoration; it forms the facing of walls in interiors; it paves floors. Bas-reliefs, piers, capitals, arches, shafts, corbels, chancels and arcades are composed of it.

Terra-cotta, the most enduring of all building materials, has been used to a greater or less extent from a high antiquity in continental Europe, and in England terra-cotta trimmings were used in building as early as the fifteenth century. In the United States this material does not seem to have been introduced until after 1850. Experiments were made in this direction in 1853 by Mr. James Renwick, a prominent New York architect, but the innovation was not received with favor by builders. In 1870 the Chicago Terra-Cotta Company brought over from England Mr. James Taylor, superintendent of the well-known works which were established by Mr. J. M. Blashfield, in 1858. By the introduction of the English methods, the Chicago establishment soon turned out better work than had been before produced in the United States.

The Perth Amboy Terra-Cotta Company was incorporated in 1879, and at once embarked in the manufacture of large designs for architectural purposes from clay obtained from the neighboring deposits. The plant of this company has expanded so rapidly that at present it includes twenty-two kilns, some of them measuring forty-eight and one-third feet in height and twenty-four and one-sixth in diameter, (see frontispiece) which are said to be the largest of the kind on this continent, if not in the world.

The company has in its employ a number of eminent artists in this particular line, and has furnished terra-cotta details for many prominent buildings throughout the country. Of these we may mention Young Maennerchor Hall, Philadelphia; Ponce de Leon Hotel, St. Augustine, Florida; Biological Laboratory, Princeton College; and Central School, Ironton, Ohio.

Since about 1880 the demand for architectural terra-cotta has rapidly increased, and to-day many manufactories are in operation in various parts of the country. In the latter part of

1885 the New York Architectural Terra-Cotta Company was organized, and the services of Mr. James Taylor secured as superintendent. The works at Long Island City have furnished designs for more than two thousand buildings, scattered throughout the principal cities of the Union. They have lately succeeded in producing a pure white terra-cotta, which is said to be fully equal to the red in durability and hardness, and they have used this latest invention, in combination with buff brick, in the rebuilding of Harrigan's Theatre, New York. The effect is novel and pleasing. Other architectural terra-cotta works have also been recently experimenting in the same direction, and it is now only a question of a short time when the more perishable marble, as a building material, will be superseded by this more enduring substitute. Having eliminated the red coloring matter from the composition, it would seem possible, by the introduction of other tints, to produce terra-cotta in yellow, blue, or any shade desired. The possibilities in this direction appear almost limitless.

The Indianapolis Terra-Cotta Company, located at Brightwood, Ind., commenced business under its present management in 1886. Mr. Joseph Joiner, a gentleman of large experience in this field, and a highly qualified architect, superintends the manufacturing department.

In the same year, Messrs. Stephens & Leach started a factory for architectural terra-cotta in West Philadelphia, Penn. and later the firm name was changed to Stephens, Armstrong & Conkling, and later to Stephens & Co., which concern is now run as a branch of New York Architectural Terra-Cotta Co. During the nine years of the works' existence it has furnished material for hundreds of important structures in Philadelphia and other cities, of which particular mention may be made of panels and gable work in the library of the University of Pennsylvania, and the Drexel Institute, erected in West Philadelphia. A series of animal-head medallions, in high relief, are particularly excellent, and some bas-relief portraits of eminent men, modeled by such sculptors as H. J. Ellicott, John Boyle, and E. N.

Conkling, are among their best productions. Specimens of the work of this company are shown in Figs. 166 to 172, and of the New York Architectural Terra Cotta Co., in Figs. 173 to 181. Admirable work is also being produced by other establishments in Boston, Chicago, and most of our larger cities.

FIG. 166.

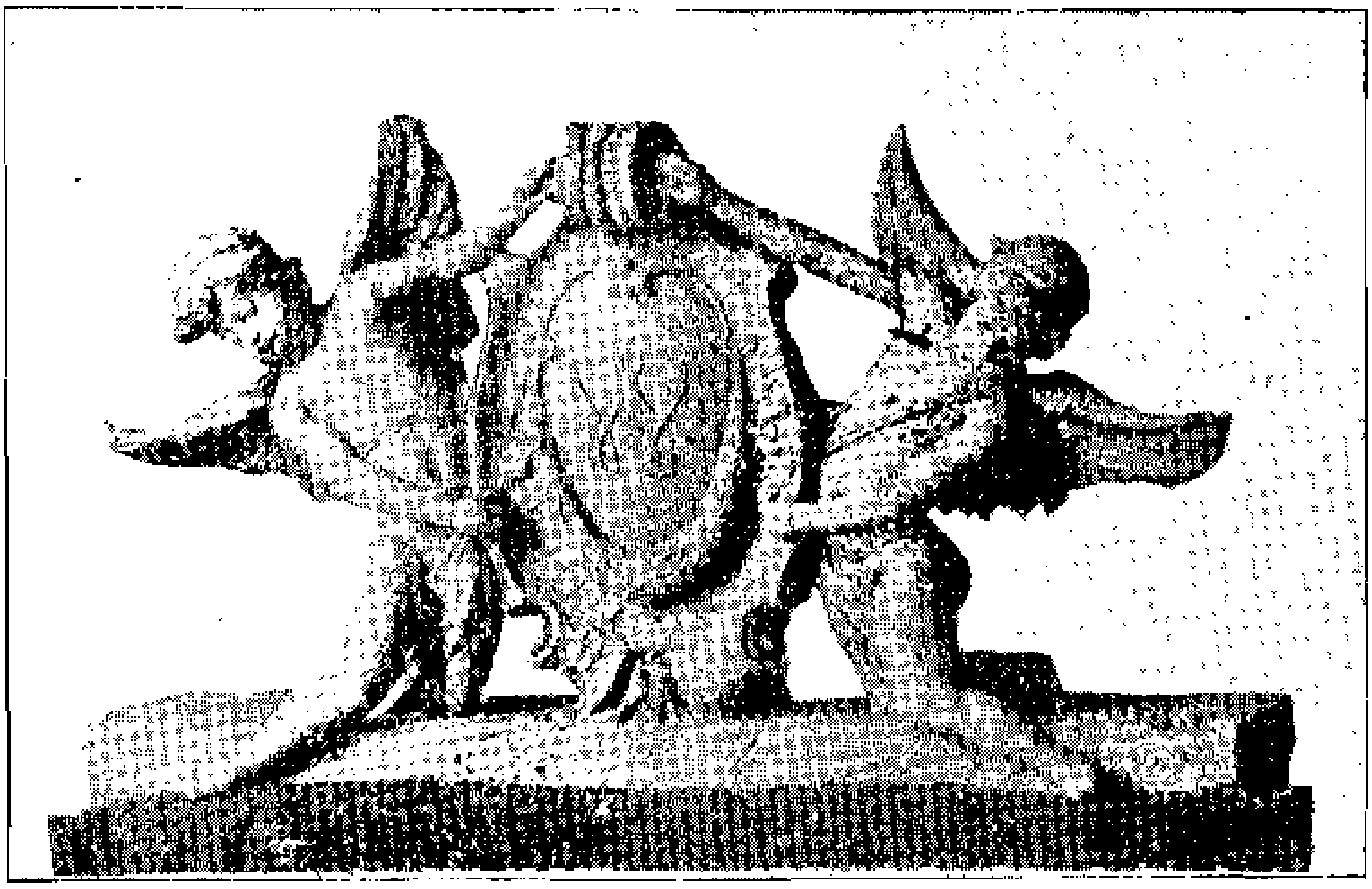


FIG. 167.

FIG. 168.

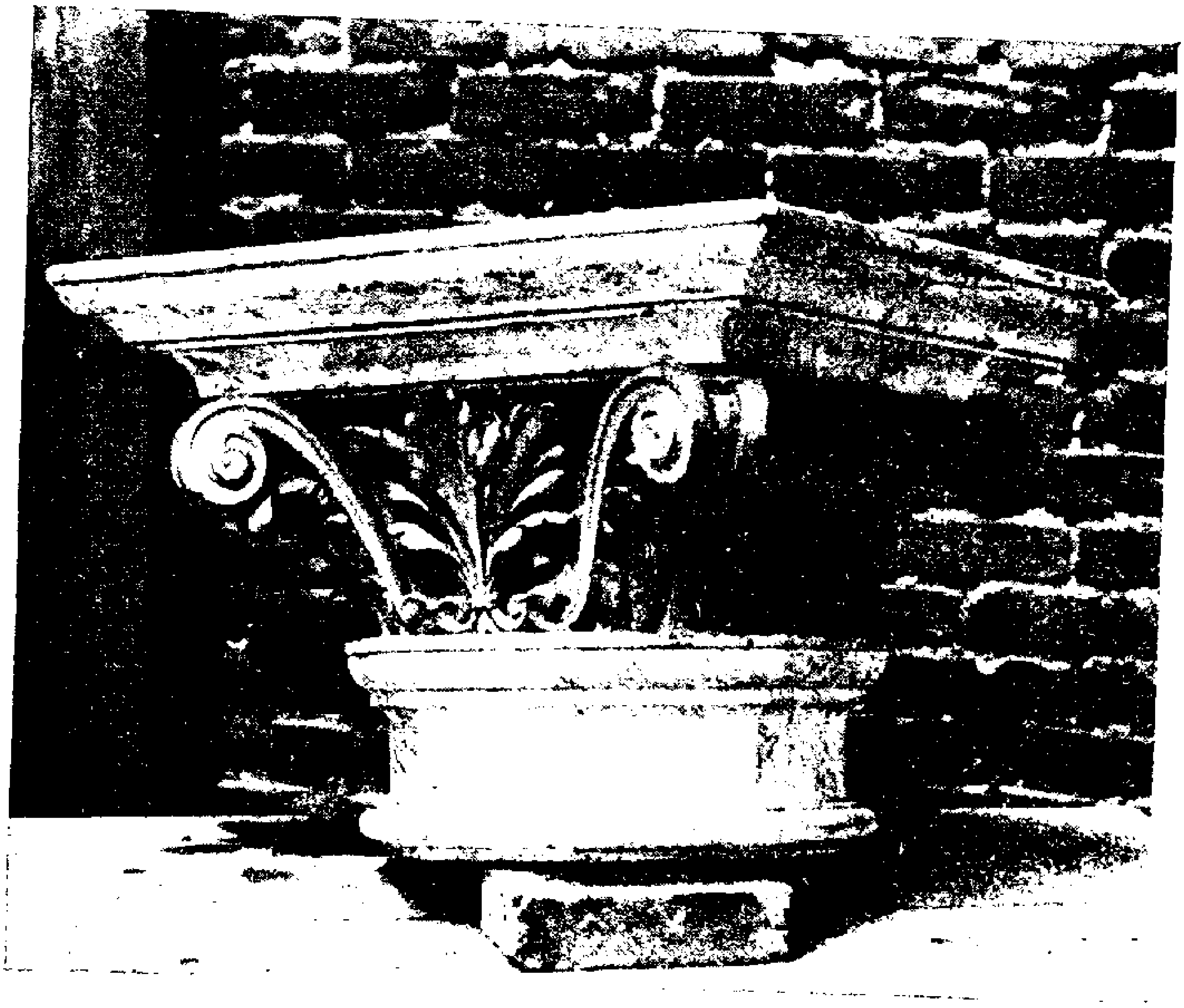


FIG. 169.

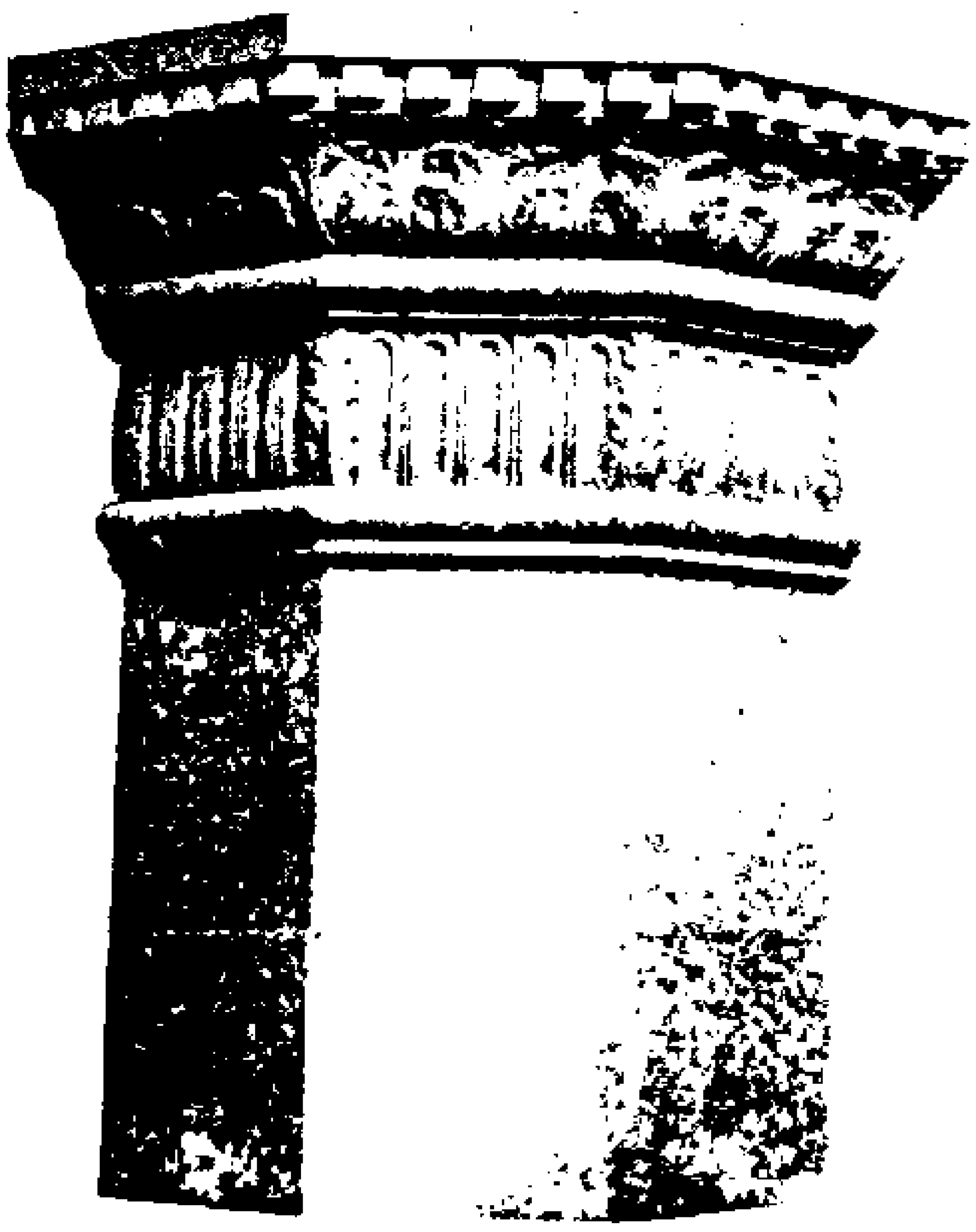


FIG. 170.

FIG. 171.

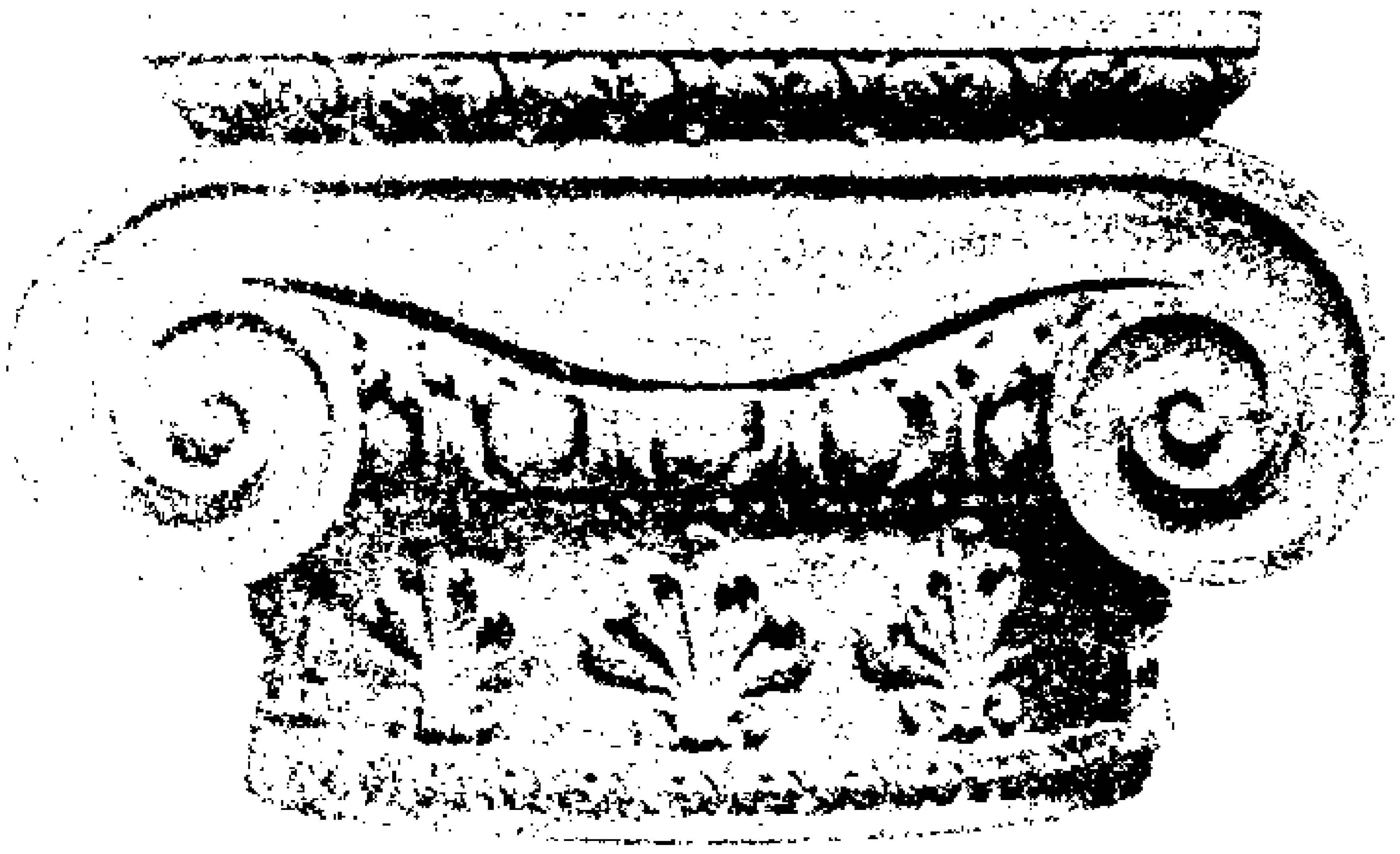


FIG. 172.

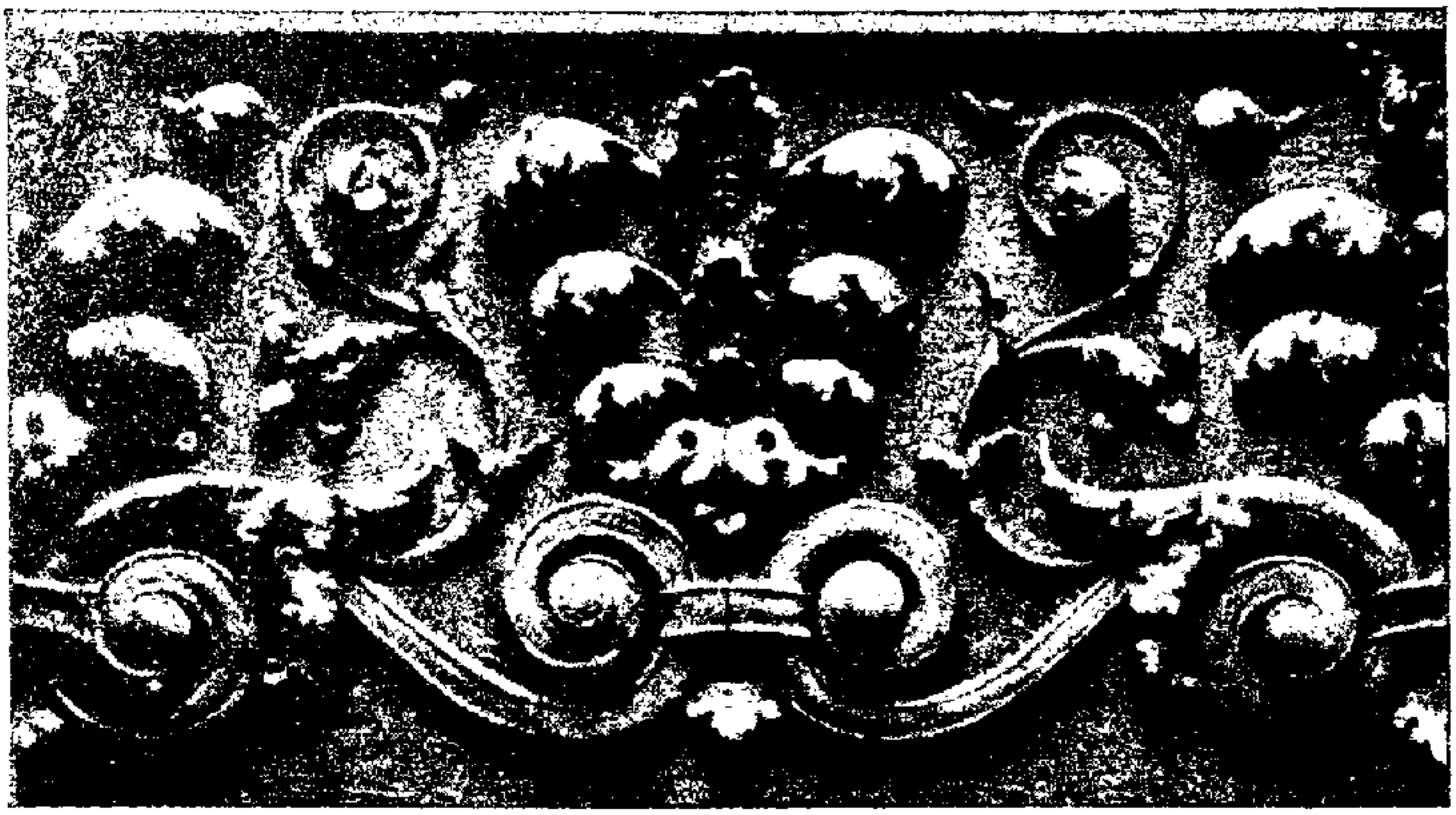


FIG. 173.

FIG. 174.

FIG. 175.

FIG. 176.

FIG. 177.

FIG. 178.

FIG. 179.

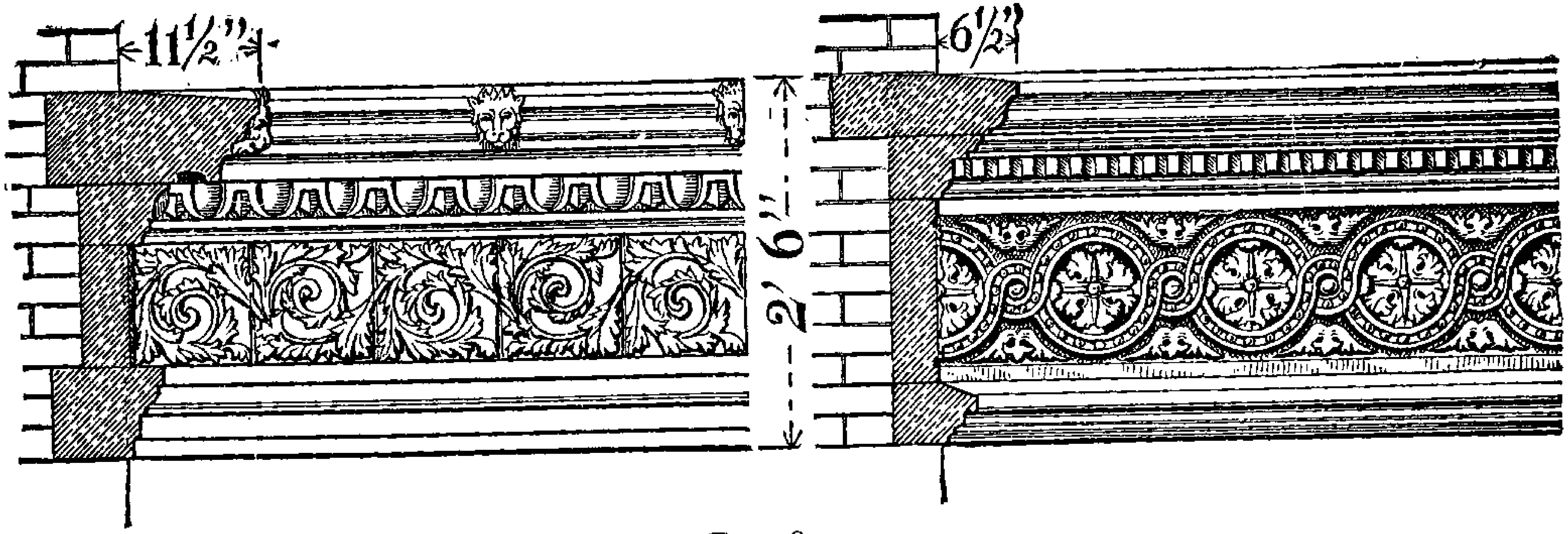
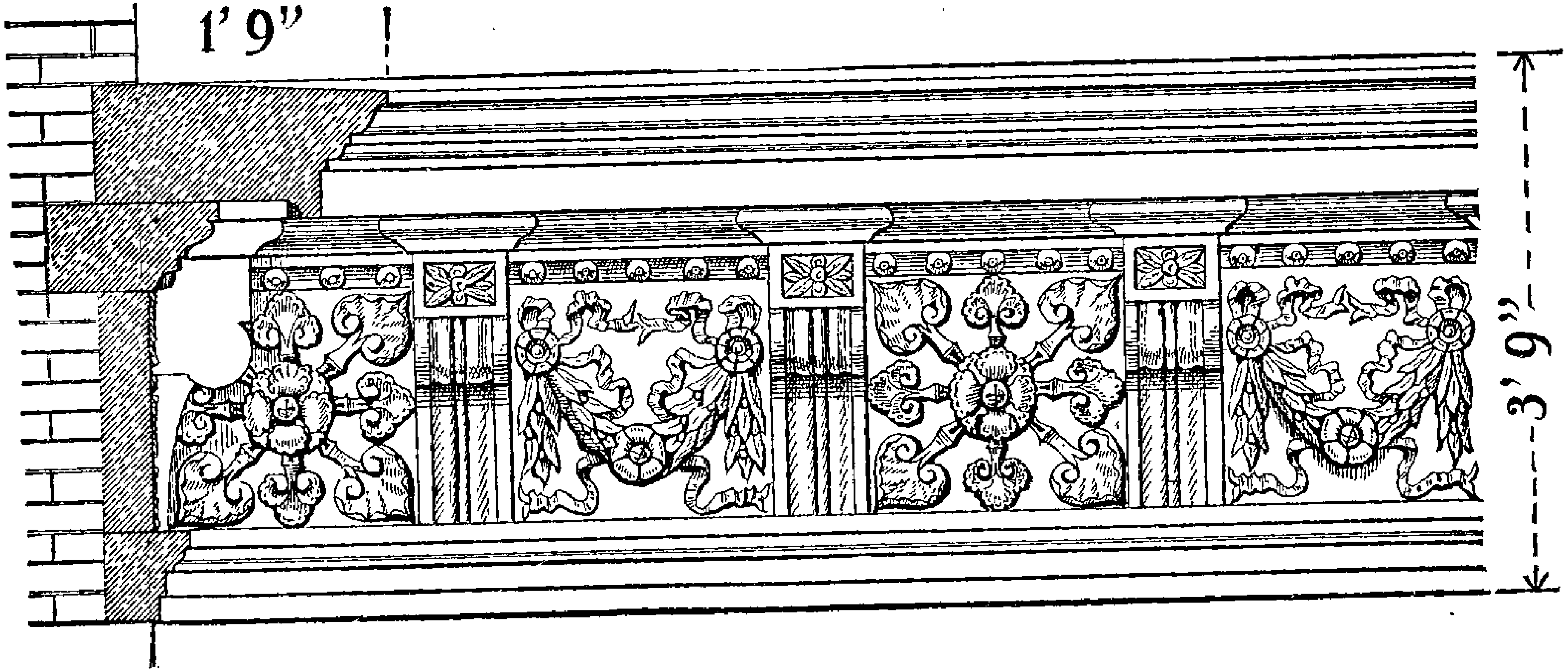


FIG. 180.



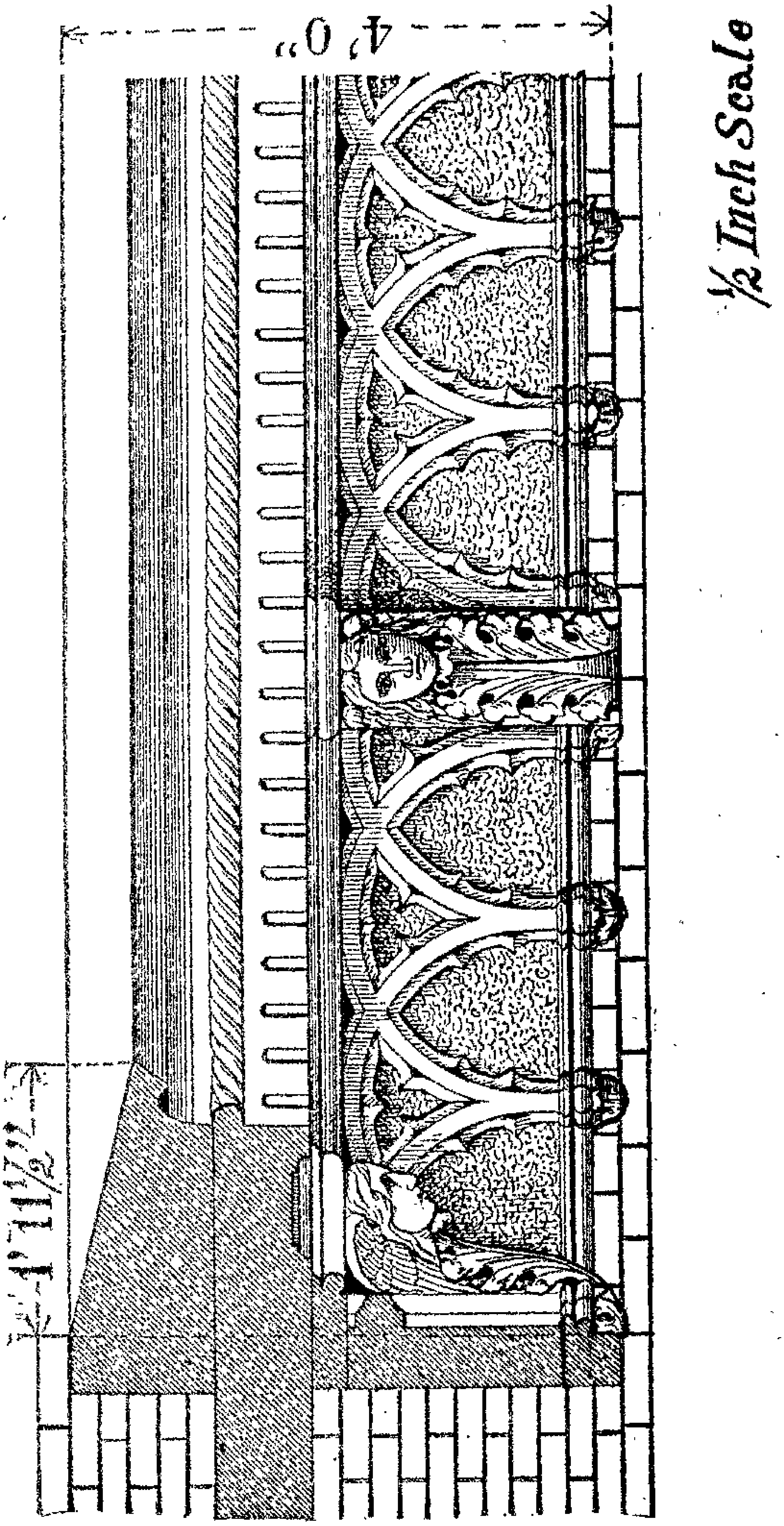


Fig. 181.

The evidences of the material prosperity of this country are probably more fully displayed in its street architecture than in any other manner. With the marvelous increase in real estate values during the past twenty years, there has been a coincident

growth in the size and decoration of its buildings. The concentration of commercial and social interests has created a demand for vast structures; the accretion of wealth has given the means to erect them; the immense advance in the ability of iron workers has furnished the skeleton, while the clay workers have provided a large part of the material necessary to complete the form. I* say a large part, for the student of architectural design in this country will not only find that there are very few noticeable buildings anywhere which have been erected more than twenty years, but also that a very large proportion of the structures which attract his attention are dependent upon terra-cotta work for their enrichment.

Now an examination of the designs of these buildings will, I believe, divide them into two classes.

First.—Designs in which terra-cotta has been used as a stitute for stone.

Second.—Designs in which terra-cotta has by its facility of formation furnished the architect with a freedom of expression that enabled him to give scope to his fancy and produce results impossible to the school of line, square and plummet. The further fact will also become apparent, viz: that much of the recent great advance in freedom of design in this country began with the advent of the architectural terra-cotta worker.

When the use of burned clay in other forms than common brick was suggested to our architects, they at once gravitated towards two distinct ideas:

1. Terra-cotta as a substitute.

2. Terra-cotta as a distinct "building material."

Some architects were attracted by the hope of having found a cheap substitute for stone, which would enable them to get more show for less cost. Such architects would ask for large pieces, rock surfaces and stone colors. They would select a chip of natural stone, and demand that the clay-worker do an impossibility, viz.: reproduce that exact shade of color [illegible]

* From an article by Mr. James Taylor.

ing the fact that the color of the stone is in a great measure due to the texture of its surface.

Stone work always presents a section of the material and shows the grain, while terra-cotta always presents an outer skin produced by the concentration of the finer particles of the clay at the surface of the mould in pressing the material into the desired shape. In stone the carved work differs in color from the plain surface. Yet the material is identical.

As to uniformity of color in terra-cotta, it can only be obtained in one way, and that is available—let the painter have a chance.

The pursuit of cheapness never yet had any artistic value; therefore it is useless to expend thought on the question of terra-cotta as a substitute or sham building material. Terra-cotta is a valuable material; it has a practical utility and is capable of artistic expression in architecture. It is the materialized crayon sketch.

The proper use of terra-cotta demands:

1. Moderate size of pieces.
2. Manipulation of the surfaces.
3. Consideration in the construction.*
4. Protection of the exposed joints.
5. Freedom of shade in color.

It must always be remembered when making designs for execution in terra-cotta that the material is plastic during all the processes of manufacture. It has to be pressed into plaster moulds to give it the desired form, then it has to be dried before it can go into the kiln, during which processes it will contract and lose about one-twenty-fourth of its bulk and one-twentieth of its weight. This shrinkage continues during the process of burning, and makes the total contraction about one-twelfth and the reduction of weight about one-fourth. If the size and form are moderate, this shrinkage will be obtained

* What I wish to insist upon is the necessity of taking into consideration the material used in construction. Thus: Iron can be used as beam lintels, stone may sometimes be so used too, but terra-cotta should never be so used. James Taylor.

without cracking or distortion and with but small risk of failure. The same conditions affect the surfaces of the material; unequal drying causes varied contraction, which the high light of sunshine apparently magnifies; therefore terra-cotta should never have a smooth surface for exterior work. Many treatments of surface are in vogue, such as tooled, combed, stippled and crinkled finish; all of these are used to convey the idea of a soft and plastic material.

The use of terra-cotta sometimes leads to great errors in construction. It is customary to speak of terra-cotta as being light in weight; but this is only true in regard to transportation of the surfaces, for when terra-cotta is set in place and properly filled (so as to preclude the formation of pockets of water, which means ice in winter), it becomes the same actual weight as brickwork and very much of the same construction, therefore all excessive projections, spans or openings ought to receive a good and sufficient backbone of iron construction.

There are instances in New York City where cornices with three feet of projection are simply covered with inverted boxes of terra-cotta, each box capable of containing many gallons of water, and at about every two feet there is a convenient joint, which, when the pointing becomes a little loosened (as it will), will freely admit the rain water and let it soak into the walls, so that in the winter time ice will be formed in these boxes and breakage may result. Surely this is not the fault of the terra-cotta, though the material is often blamed in such cases. In a a climate of such extremes as ours, it is evident that all upper surfaces which are traversed by joints ought to be covered by some sufficient protection.

Almost all of the finest buildings in our cities are disfigured by grimy and black streaks leading down from the vertical joints in the stone cornices or projecting mouldings. This could and should be prevented by the use of metal or other flashings for large projections, and raised joints for the smaller ones. In the use of terra-cotta this is imperative; for careless workmen will often neglect to fill in the work properly when it

is being placed in its permanent position. Water and ice will then in due course cause trouble.

The color of terra-cotta is a frequent cause of contention. It ought not to be. Absolute uniformity of color is beyond the possibility of manufacture. It should be remembered that the tone of color is governed by the chemical constituents of the clay, and the shade of color is governed by the degree of heat involved in burning—a few degrees more causing the darker shades, or a few degrees less producing the lighter shades. The regulation of the heat of a kiln of burned clay (during the process of firing) within certain limits is at present beyond the ability of the most experienced of our clay workers. Hence it is unfair to ask it of them. If the question of shade of color is important to a certain design, as we have said, why not utilize the painter? He has a recognized field in the decoration of wood and iron. Is there any sound reason why he should not also decorate the terra-cotta work? Mechanically there is none, for a coat of lead paint will last much longer upon terra-cotta than upon any other building material ever used, not excepting wood or iron.

A study of the relations of terra-cotta to architectural design, founded upon a practical knowledge of this material, will surely enable our architects to produce an ideal brick and terra-cotta structure, which shall as truly make its mark in our day as did the Certosa of Pavia, the Church of St. Rustico at Caravaggio, the Cathedral of Cremona, and other buildings of Northern Italy, centuries ago.

A TERRA-COTTA FACTORY.

The departments or divisions of the work in a terra cotta factory seem to indicate a five-storied building as the most convenient for the purpose, the divisions being as follows:

The basement or first story for the milling and storage of the prepared clays and for the operations which belong to the firing of the kilns.

The ground floor or second story for the loading and unload-

ing of the kilns, and for the selection and fitting of the burned product previously to its delivery to the store or purchaser.

The third story for the pressing and finishing and drying of the heavier, coarser, and most bulky pieces of terra-cotta work.

The fourth story for the pressing, finishing and drying of the smaller ornamental and finest description of work.

The fifth story being reserved for the studios of the modelers and for the model and mould-making shops.

The model and mould-making shop is the most important portion of a terre-cotta factory, and like the head of a man, should be at the top, so as to be as far as conveniently removed from the dirt and noise of the other departments.

In this department are prepared the models and sculptures of the business, and the moulds from which the clay duplicates are to be made.

The idea of the architect having been conveyed to the top story, there takes a substantial form for the first time, and becomes a material having size and weight.

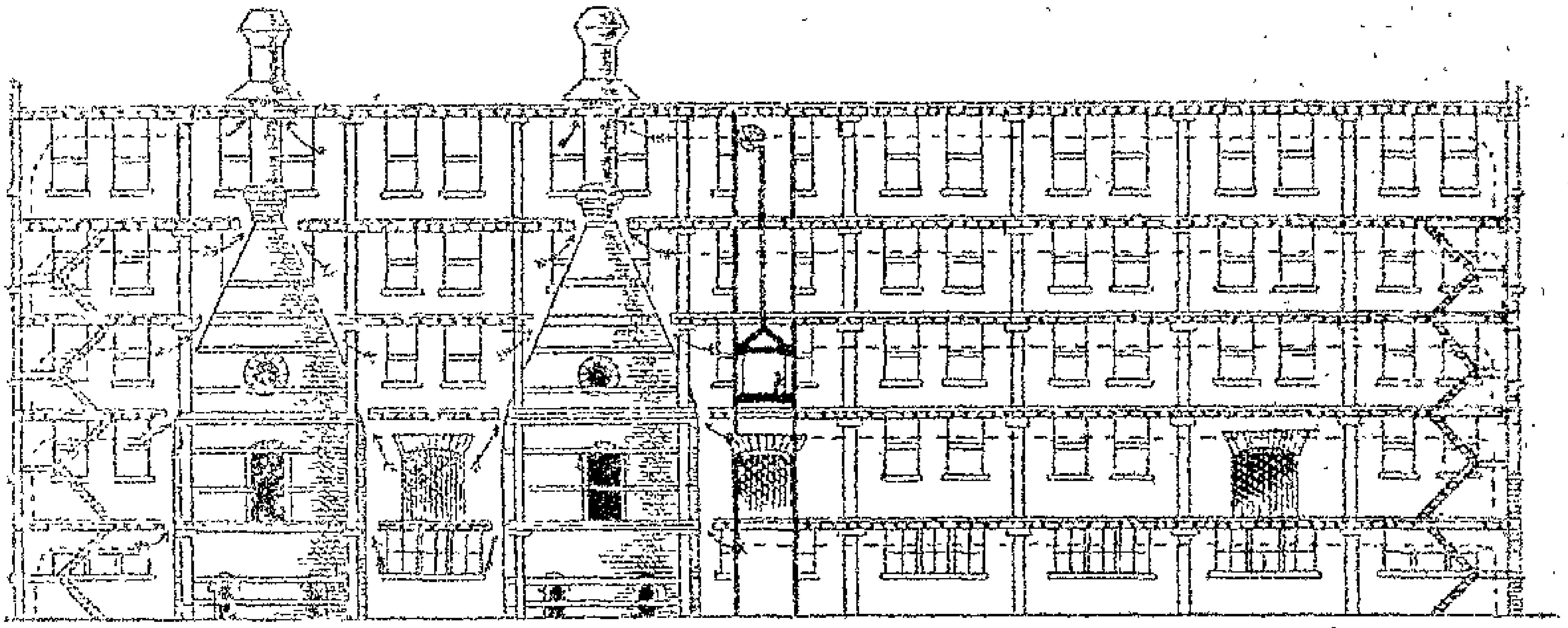
It then passes downward, and as in all orderly progress does not retrace its path; if it is of a decorative or artistic quality, demanding skilled labor rather than mere material, it stops awhile on the next story to be put into its proper progression.

Panels with modeled surfaces, sculptured forms, finials, mantels, and any other delicate works, are thus done next to the top, just as all the higher employments of men, such as sculpture, painting, writing, calculating, etc., are performed with the hands in close proximity to the head. Should the work, however, be of a heavy, coarse, or bulky nature, such requires more muscular force, less mental service, and a greater amount of material; it goes a story lower to pass into its next stage of progress.

In the production of one ton of terra-cotta ware there are required to be used nearly 700 pounds of water, or more than 80 gallons. About 70 gallons of this surplus moisture will have to be evaporated in the process of drying, and the final 10 gallons will pass off after the work is placed in the kiln in a form known as water-smoke.

By making the factory structure several stories in height and placing the kilns at one end of the same building without any intervening partitions, it will be found that by the evaporation of the moisture the drying of the work can be carried on in a very economical manner.

FIG. 182.



BUILDING FOR TERRA-COTTA FACTORY.

Fig. 182 will be found useful for illustrating the practical workings of this method; the sketch represents a building five stories in height, with the kilns located at the northern or cold end of the building.

It will be noticed that the kilns are placed at one end of the shops and grouped together, so as to concentrate their heating capacity in one place as much as possible. This is done in order to create a constant stream of air flowing toward them from all parts of the workshops, attracted by the well-known law which causes the heavy or cold air to rush toward the warmer or lighter air adjacent; and these generators of draught should always be placed at the northern or coldest end of the building.

The floors and the roof are not allowed to come in contact with either the brick or iron-work of the kilns, but there is a clear space averaging eight inches all around them, which forms a passage for the moistened air to escape upward and outward, as is indicated by the arrows and dotted lines in the illustration.

This area or space is covered with an umbrella-shaped hood about eight inches above the roof-line, which prevents the rain or snow from driving into the building.

The iron smoke-stack which passes through the top story should also be so constructed as to assist the ventilation in the same direction.

This smoke-stack should consist of a cylinder of light boiler iron, and be made smoke-tight to carry off the smoke and surplus gases created by the combustion of the fuel used in firing the kilns.

This cylinder is inclosed within another cylinder made of the same kind of iron, but of sufficiently large diameter to allow of a space of four inches between the two cylinders for the purpose of providing an air-flue.

The outer cylinder or jacket is pierced with holes one inch in diameter placed six inches apart diagonally.

When the inner or smoke-stack becomes heated by the fire below it creates a vacuum in the air-flue, and at once the air of the workshop rushes in as indicated by the arrows, and thus passes up and out under the umbrella.

This jacketed and ventilated smoke-stack will also form a perfect protection from fires that might be caused by an overheated flue, because it is impossible to overheat the pierced jacket; for the hotter the smoke-stack becomes the greater the rush of air into the air-flue, and consequently the greater the ingoing draft of cold moist air.

The elevator-shaft in the centre of the building and the stairways at either end are open, that is they have no partitions except those high enough to prevent persons falling through or walking off.

By these arrangements all the air as it becomes heated rises toward the kilns and escapes from the building at the roof, taking with it a large portion of the surplus moisture.

Another important feature of this system of ventilation is the method of making the window-sashes. These should be numerous, and made to slide up and down as is usual in house-sashes,

with this exception: only the upper sash ought to have pulleys and weights to allow of it being lowered at will; the lower sash ought to be a fixture, and the sash-frame should reach as near to the ceiling as possible, so as to allow the highest strata of air to pass out easily when the windows are open.

The advantages of such sashes are readily seen. First, the workman can only open the right sash—the top one. Second, there is no draft upon the work or upon the workmen, and yet there is an abundance of fresh air constantly passing through the entire work-rooms. The inlet of air will always take care of itself, provided the builder will furnish the outlet and some motive force to accelerate the motion; this is done in the above-described method by the radiated heat of the mass of brick-work and the iron chimneys of the kilns, which heat, if not so used, would probably be wasted.

Experience teaches that no matter how perfect the ventilation, it will not suffice to dry out the surplus moisture quickly enough for profitable working without the aid of some method of auxiliary heating.

TREATMENT OF CLAYS.

The peculiarities of the clays necessary for the manufacture of architectural terra-cotta have been enlarged upon in Chapter II.

Having found the clays which he considers suited to his purpose, the maker next proceeds to further reduce the natural shrinkage by mechanical means, in order to place the contraction as far as possible under his own control; upon his skill in this detail will very largely depend his success in the production of sound, straight, and well-formed terra-cotta.

There are various methods of doing this, such as by the admixture of ashes, refractory sands, crushed and ground shales, or of crushed and ground burned clay, with the crude or natural clay. The best results are obtained by the use of a proportion of the same clay burned and ground to powder, technically known as grit (some persons call it cement, but it

is hard to tell why they do so, because its use is the exact opposite of cementing). Having burned and ground to powder a portion of the crude clay, the next step is to prepare a mixture of such proper relative proportions as to make a homogeneous and workable body, or stiff mud. The exact proportions will always depend upon the quality of the clay and the knowledge of the workmen.

A safe and reliable rule will be found in aiming to make a mixture which, under sufficient burning, will contract only one-sixteenth in bulk. An easy method of finding the proportion suited to the crude clay is to measure out three separate parcels of mixture as follows:—

A. 2 parts crude clay, 1 part grit.

B. 3 parts crude clay, 1 part grit.

C. 4 parts crude clay, 1 part grit.

Mix each parcel separately, adding water enough to make a mud capable of being pressed into a mould. It is important to knead thoroughly, and have all three samples of the same degree of stiffness, then press into a mould, making each kind so as to know them after they are burned; dry slowly at the same time, and in the same temperature, and burn in the same part of the kiln.

If these trials are made carefully, they will indicate clearly what is the correct proportion of clay and grit to be used in order to produce good terra-cotta.

In judging of these trials it will be important to notice first the form, second the hardness, third the shrinkage, fourth the color.

The form determines the marketable quality, the hardness indicates the durability of the form, the shrinkage demonstrates its working limits, while the color is capable of adjustment and is therefore of least consequence.

When the exact proportions of admixture known as body, which will reproduce good forms, in a semi-vitreous material of approximately correct size and of a reliable color, has been ascertained, the next step to consider is how to prepare it in the most economical manner.

There can be no question of the value of the slipping or washing of all clays for terra-cotta work. This is the method adopted by Ernest March at Charlottenburg, and where the area of the works and the available capital will permit, it should always be done, indeed it must be done for high class work.

For ordinary work many of the advantges of the washing process can be obtained by the use of a cylinder-crusher and stone-separator for plastic clays, and the use of a pulverizer for clays that are of a shaly quality, such as Indiana clays, obtained from the block coal regions, and many other clays that are mined in the neighborhood of coal-fields. The kind of machinery to be used must be determined by every manufacturer for himself. The nature of his clay will indicate what work he ought to do in order to properly prepare and temper it. Every machine has some especially good feature, while no one is absolutely perfect, or suited to every description of clay or work. Therefore, in selecting machines, it is well to get only those which can readily be understood and operated by the purchaser. Clay-working is like farming, as shown in the maxim "The man is of more consequence than the land," so in our case the man is of more consequence than the machine.

When the clay-reducing plant has been selected, the next step in order is to prepare the grit. For cheap and coarse work, sharp and semi-vitreous sands will be sufficient, but for making a uniform grade of body, of good color and density, there is no better material for grit than some of the crude clay burned, crushed, and ground to a powder so as to readily pass through a 16-mesh sieve.

This can be readily and cheaply obtained by putting lumps of clay in all available vacancies among the goods in the kiln. The burning thus costs nothing, because the lumps hold the heat better than air-spaces, and the saving of fuel will fully repay the labor of putting in and taking out.

Having the crude clay and ground grit in condition, we are now ready to think of the best way to prepare the batch or mixture. Where the space, water, and power will permit, it is

best to run through a washer a stated quantity of clay reduced to a thick semi-fluid condition. This by being allowed to flow through a long trough having a broad flat bottom, and some trap provided, will leave all stones and refuse behind in its progress from the washer to the pit or pan. After this given quantity of clay has been sent to the pit, allow it to stand for awhile until the settlement of the clay has allowed the water to gather on the top. A simple contrivance will form a well in one corner of the pit into which almost all the water will run; once there, the water can easily be drawn off by a syphon of rubber tube. When the water has been taken away, the grit can then be evenly scattered over the whole surface, and any other material which the workman deems necessary to a good terra-cotta body. This alternate deposit of washed clay and scattered grit, etc., is repeated until the pit is full, and the whole allowed to rest until it is stiff enough for the pugging process.

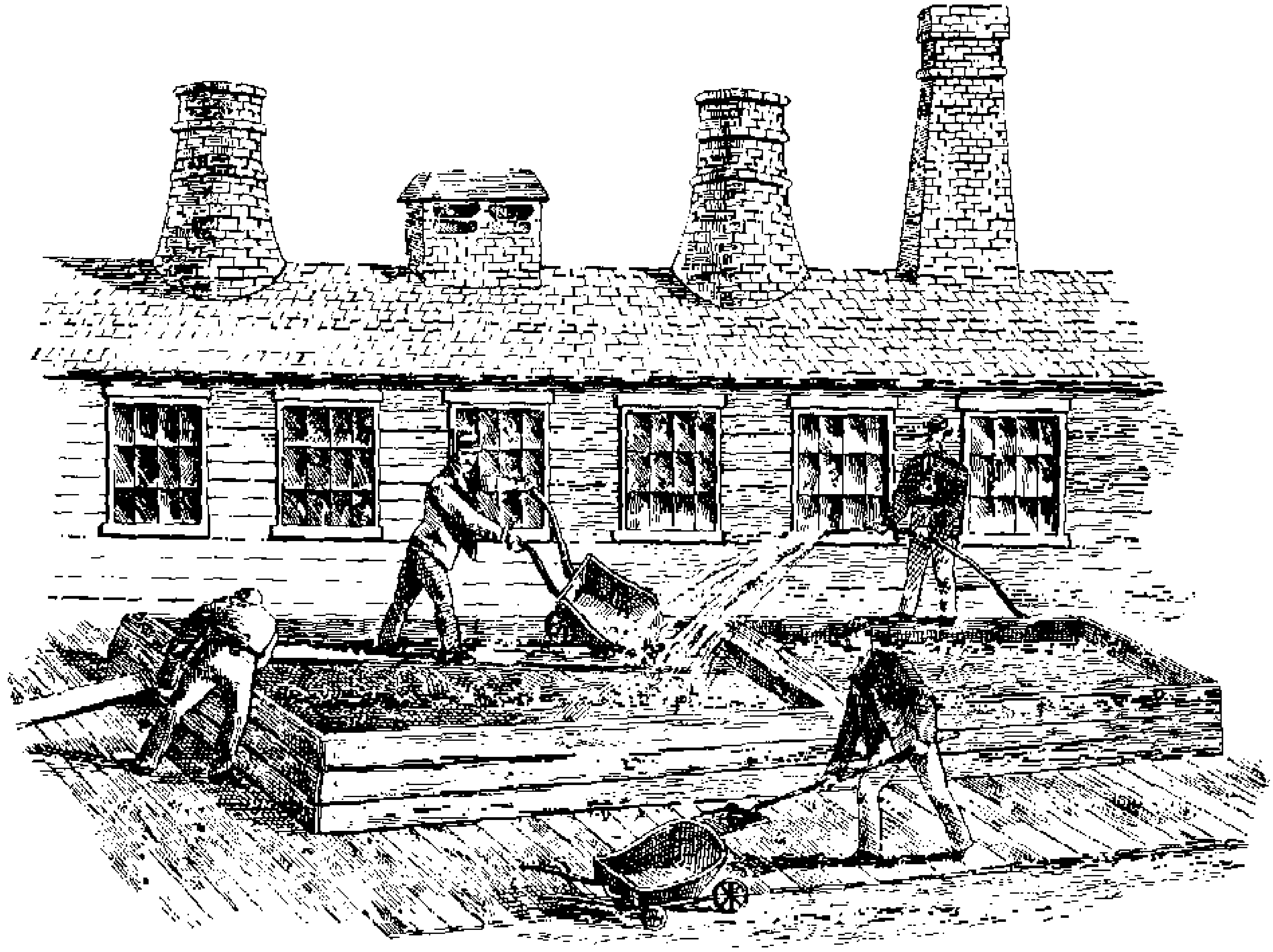
Another method, when space is limited, is to prepare a level platform about 25 feet square, as shown in Fig. 183, which will give a little over 600 feet of surface, and is capable of holding 50 tons of mixed clay.

As soon as the platform is ready, spread over it evenly forty-five wheelbarrow loads of clay that has been passed through the rollers or pulverizers, as the case may be, *each load being strike measure* of about 300 pounds; use a standard size of wheelbarrow for all material, and insist upon the workmen using a striker to insure equal quantities in each wheelbarrow. This will save much unnecessary expense in weighing the different materials used in the mixtures, and insure uniformity.

When the crude clay is leveled off to a regular thickness, scatter on the top of it the predetermined proportion of sand or grit. While the grit is being spread over, have a trustworthy man with a hose and coarse sprinkler pour on a steady stream of water sufficient to wet the mass; this will wash the grit down into the interstices of the clay lumps, and aid greatly in the mixing afterwards. It will be found useful to mix at least five batches, one over the other in each mixing, as this will give

about 45 tons, and it will help to avoid differences or errors in mixing, as it will be certain that the 45 tons will be all alike if care be taken in moving it from the platform to the mill, and from the mill to the pit. After spreading the five batches, go around the edge of the mass and trim up all the loose material, throwing it upon the top of the pile, taking care to keep the

Fig. 183.



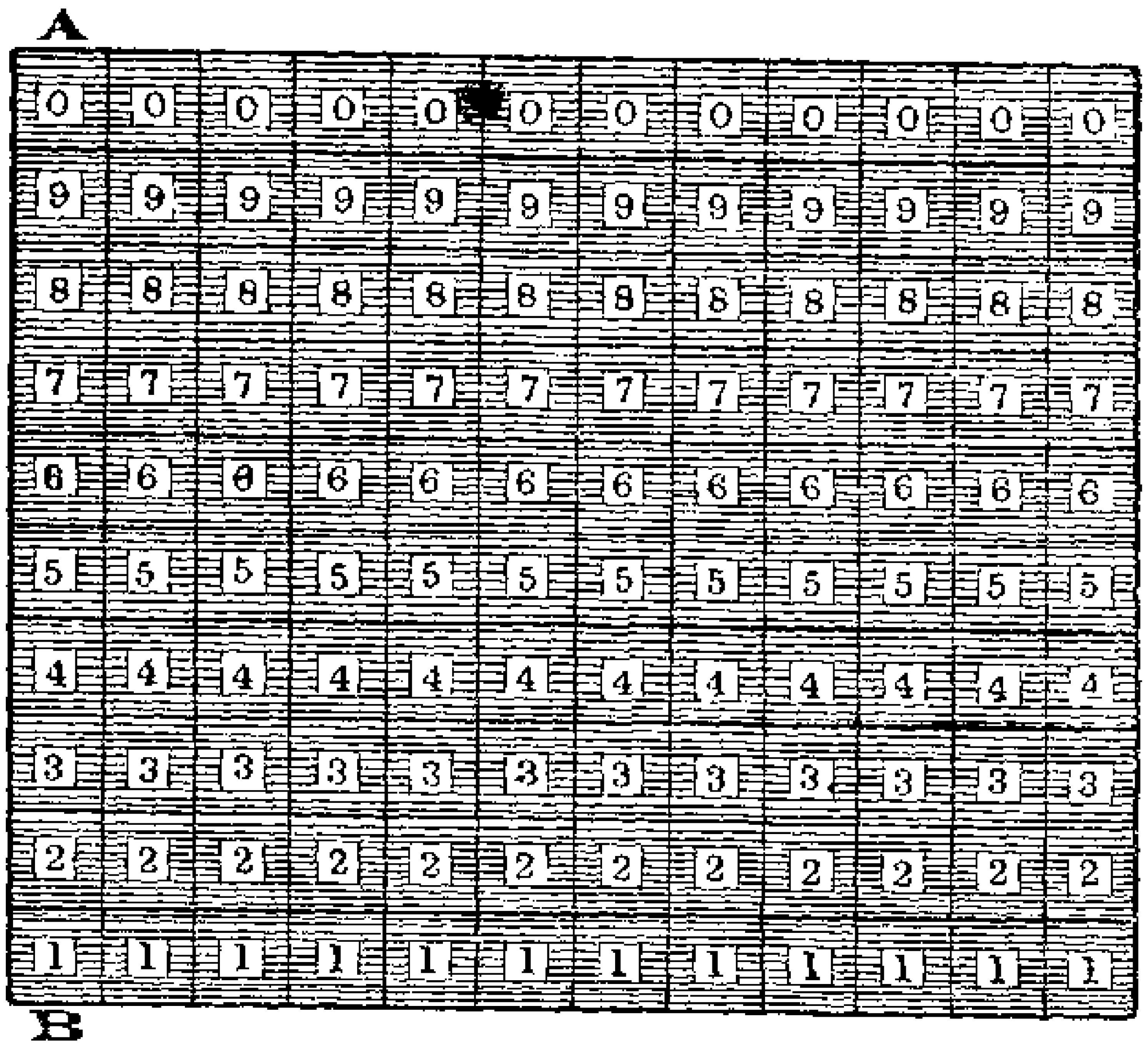
PLATFORM FOR MIXING CLAY.

top level. Then begin on one side cutting square from *A* at the top to *B* at the bottom, and pass the mixture through a pug-mill regularly; then spread it evenly over the surface of a storage pit as level as it was before on the platform. By this process the vertical section of the platform strata will become the horizontal section of the pit strata, and it will be scarcely

possible for two shovelsful to come together in the pit in the same relative positions which they occupied on the platform.

Fig. 184 represents five batches of clay and grit laid up in

FIG. 184.



alternate layers, the whole being about 45 tons of dry material. *A* and *B* indicate the directions of the vertical slice to be cut off in taking the clay mass to the pit or cellar by way of the pug mill. The figures in cubes are seen to lie in uniform planes, but when the vertical section becomes the horizontal section by lying in the pit as described above, it will be found that the cubes will be mixed as indicated in the next cut. Fig. 185, where *A* and *B* form the bottom layer instead of the end, as in Fig. 184. Fig. 185 represents the change of position of each cube after being placed in the pit. This system prevents either the clay or grit from predominating in any part of the mass. The clay, after mixing, should remain at least one month in the pit before tempering it in the pug-mill.

There will always be a wide difference of opinion as to what kind of machinery is best suited to the purpose of preparing clays and mixtures of clays and rendering them available for the use of the terra-cotta maker.

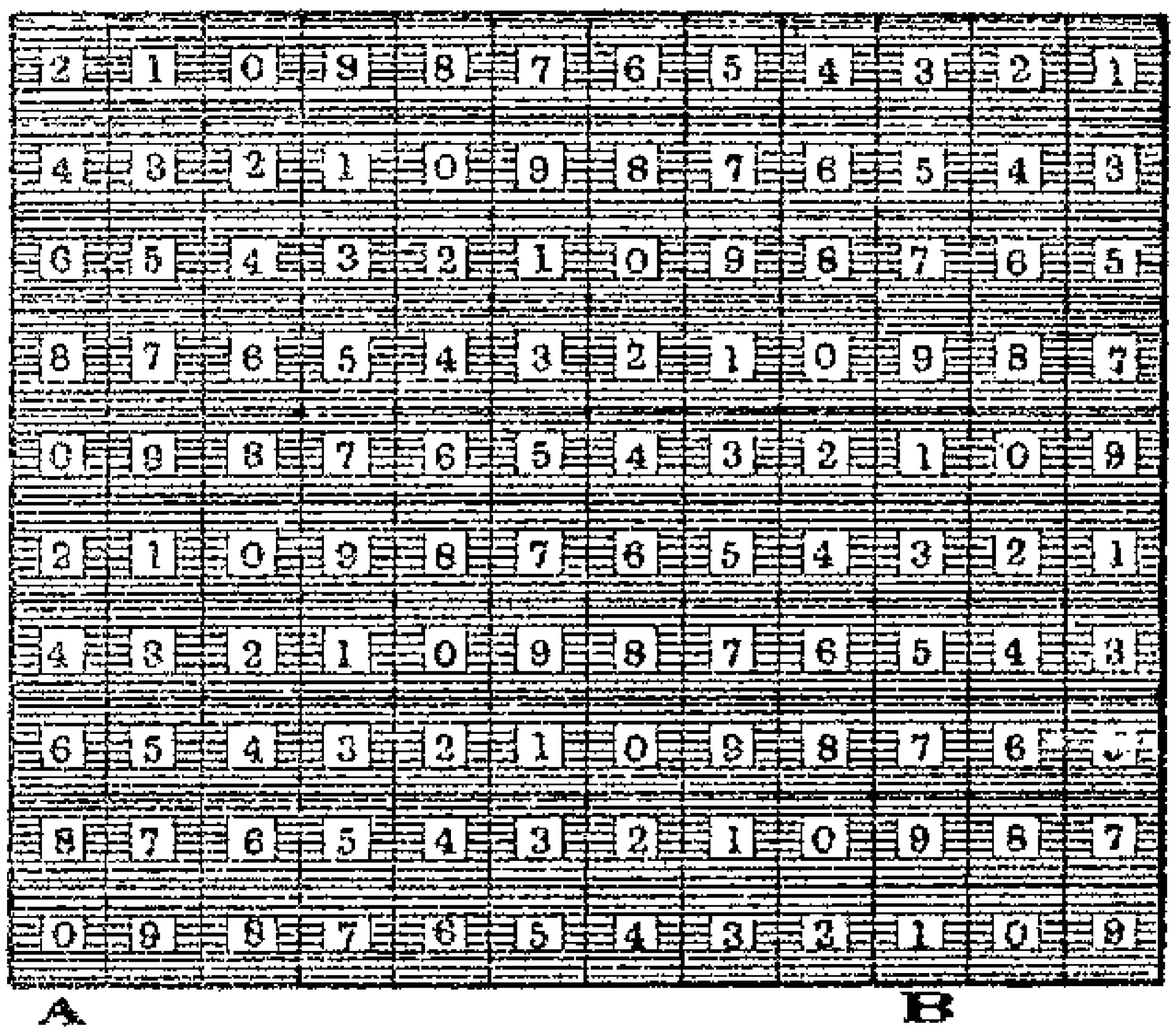
It ought not to be expected by any practical clay-worker

that any one machine should prove itself of universal capacity and fitted to manipulate every description of clay.

There are various and sufficient reasons for this difference of opinion:

First, clays differ very much in particular qualities: some are clean, others are stony; some are tenacious and strong, others are loamy and friable; some are from deep alluvial de-

FIG. 185.



posits and are plastic when dug, while others are from rocky formations and require to be blasted when being mined, because they are in a condition resembling soft stone.

Second, the demands of the product are as varied as are the qualities of clay; we are only considering clays for terra-cotta work and brickmaking, exclusive of those used in the making of Parian, porcelain, china, and granite bodies.

Clay that has stones in it may be used by the maker of common brick if the stones are not of a limestone formation, in which case they would be changed into lime in the process of burning, and when the air or water got access to them they would burst and spoil the brick. Or, if rollers or crushers are used, they may be so reduced that they become less objectionable.

The maker of facing or moulded brick must get rid of all stones from his clay, should any exist; therefore he has to look for a better and cleaner clay. He can expel them by the use of a separator, or if they are of a quartz nature he may use a pulverizer and reduce them to power, in which case they may do more good than harm.

But the terra-cotta maker cannot afford to risk his product by any faults in his crude clays. He must have as the foundation of his stock a clean, tough clay, free from stone and loam, so that he may add to it his own proportion of grit or sand, etc. For this reason he seeks for and obtains the clays specially and best suited to his purpose.

This may seem to be an expensive method, but experience will prove that it is the truest economy. It always pays to begin right. He must have clays of different colors; some he must have brought to him in any case; therefore he can afford to purchase and freight a selection of clays, which will give him the best results after he has expended his labor upon them.

This the brickmaker cannot afford to do, for self-evident reasons.

It requires about four (4) tons of clay to make one thousand brick; these when burned will weigh about two-and-a-half (2½) tons. These, if common brick, will sell for from five to eleven dollars, according to the market and the quality. If the bricks are facing or moulded bricks, they will sell for from fifteen to eighty dollars per thousand, according to the quality, color, and design. Thus, brick clay, when manufactured into common brick, will produce only from two dollars to three dollars and seventy-five cents per ton, while even the better grades of facing brick will produce only from five to sixteen dollars per ton; and even the moulded brick will sell only for from sixteen to thirty dollars per ton. But clay, when manufactured into terra-cotta, increases in value far more rapidly in proportion to its weight. Four tons of clay will produce three tons of terra-cotta, and the value of terra-cotta ranges fron fifty dollars for the commoner shapes up to two hundred for the higher

grades of architectural work, and the average value is about ninety dollars, or more than three times the value of the best grades of moulded bricks. This difference in value in the product permits the above-described selection of clay on the part of the terra-cotta maker, and it at the same time makes his selection of machinery very simple, and reduces the cost or expense of plant and motive power.

The machines required to furnish a very effective plant are as follows:—

1st. A clod-crusher and stone-separator.

2d. A stamp-mill for breaking grit.

3d. A bur-mill for grinding grit.

4th. A clay mixing pug-mill.

5th. A good set of tempering pug-mills.

It is impossible to say which is absolutely the best machine for any of these purposes, there are so many, and so many good ones; therefore in this chapter on clay-working machinery only those machines will be mentioned which long and practical experience has led Mr. James Taylor to adopt as best suited for the purpose of preparing the *soft* or *plastic* clays for the use of the terra-cotta maker.

They are simple, require but a small amount of power, have few wearing parts, and can be operated by any practical clay-worker.

The clod-crusher and stone-separator is very necessary to crush all lumps and to remove any stones or foreign matter which may by accident or carelessness have got into the clay.

The Brewer machine has proven in practice to be a very satisfactory one for this purpose.

The next machine in order is one for preparing the grit for mixing with the clay which has been passed through the crusher.

For this work there are very many excellent machines in the market, and nearly every terra-cotta maker chooses a different one.

Some use a simple wheel of iron, very heavy, revolving in an

iron track or in a pan. Others use the Blake crusher or some similar form of alligator jaws, while some use very powerful combined crushers, elevators, and grinders. Each person sees in the machine he selects and purchases some special quality that commends it to his judgment, hence his selection.

Mr. Taylor for several years used at the Chicago works a double set of rollers for this purpose, and obtained good results from their use as crushers, but not as grinders; still, as they required too much power to work them, their use was not profitable enough to pay for repairing them, so when they became worn they were discontinued. The stone breakers or alligator jaws are open to the same charge; they cost too much for power to run them, are expensive at first, and costly for repairs, so that they are not profitable for the terra-cotta maker's use.

Few machines are profitable unless they can be fully employed. Powerful machines are costly, demand great power to operate them, and require much fuel to furnish that power. If they can be fully employed in production, doubtless they yield great results and are economical; but if they have to stand idle, it is not good policy to purchase them.

For a terra-cotta manufactory requiring not more than ten tons of grit per day, the most economical and satisfactory machine to employ is a six stamp mill, with a sixteen-inch drop, an illustration of which is shown in Fig. 186.

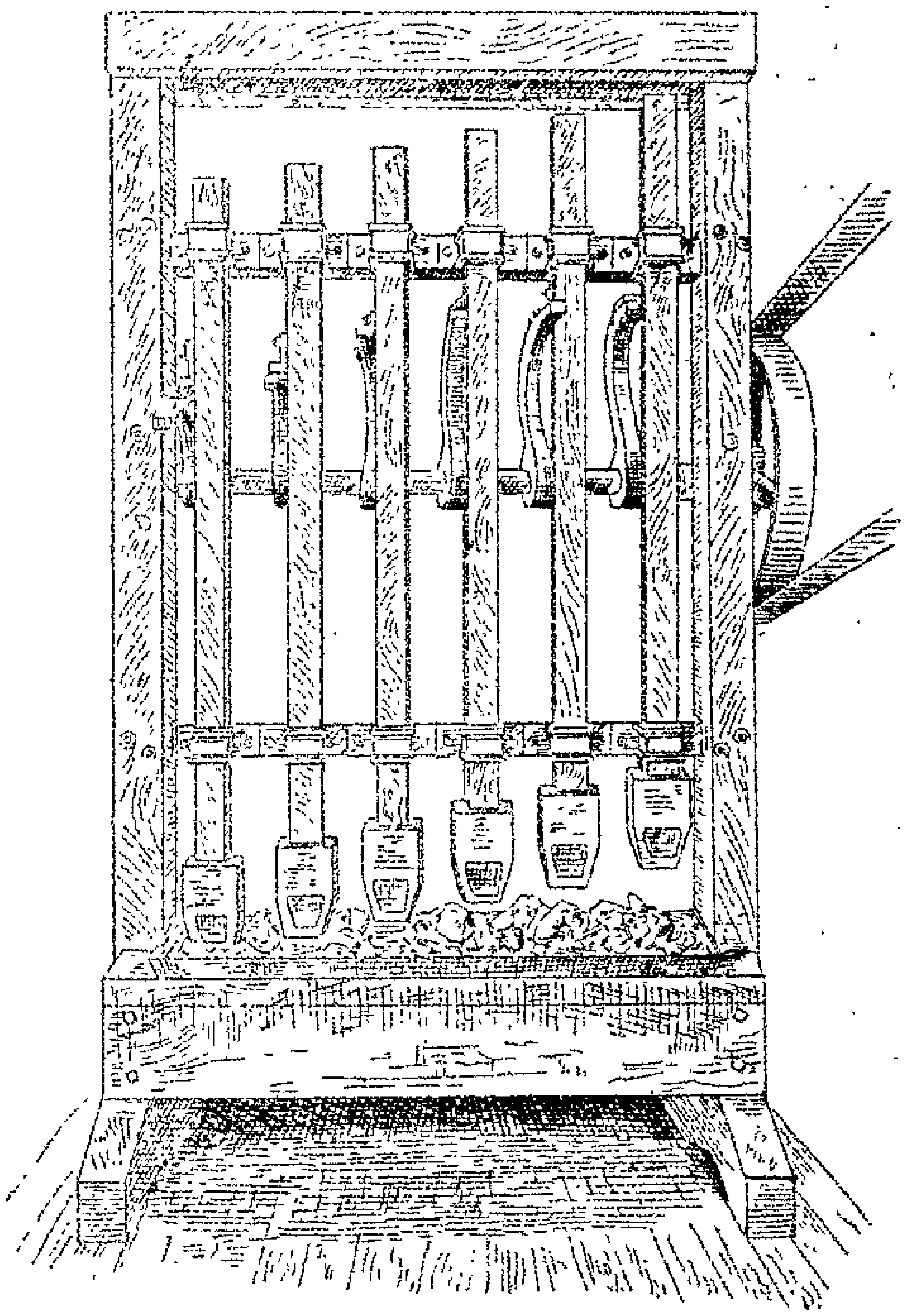
The next machine to consider is the clay-mixer. For this purpose there are many, and all of them have some good qualities. The simplest one is the old-fashioned traversing wheel and pit. This is a good mixer, and for soft mud is perhaps the best all-around machine. But for the preparation of terra-cotta clay, it is important that while the clay is being thoroughly mixed, it should at the same time be closely packed or compressed, so as to expel as much air as possible from the clay or body. This the wheel does not do, therefore it is best to use a powerful pug-mill.

With the clay-mixer the list of preparatory machines is com-

plete. From this machine the clay ought to pass into storage cellars or pits, to remain a sufficient time to allow of complete soaking or ripening; the longer this period is, the better for the material.

When the clay is required for use, it is found necessary to temper the stiff-mud to a proper consistency, so as to render it

FIG. 186.



SIX-STAMP MILL.

easy to be handled and pressed into the moulds which are to give it its destined form, so that it may take a good impress.

In doing this it is essential to have the clay thoroughly pugged, so that all stiff and all sloppy portions shall be absolutely intermixed until the whole is kneaded into a uniform condition of stiff mud. Should one part be soft while another

part was stiffer, the work would surely crack and warp in the drying, and would scarcely reach the burning stage. If the work should successfully pass through the kiln, it would be so unequal in size that it would entail much trouble and cost, and would never be a good specimen of the clay-maker's skill. In order to guard against the carelessness or neglect of unskilful workmen it is a good plan to insist upon a double pugging of all terra-cotta clays; and to insure this it is well to use a double pug-mill, passing the mixture through one, and then through the other immediately afterwards, working both at the same time.

This double mill is driven by a single belt six inches wide and of good quality.

As the geared wheels revolve in opposite directions, the motion is very steady and free from the usual clanging of ordinary machinery.

One man and two boys can attend to this mill and insure good results. The man shovels the clay into the left-hand hopper, and as it passes out of the orifice at the bottom of the left-hand cylinder, one boy catches the lumps and throws them into the hopper of the right-hand cylinder, and as it is forced out at the bottom of the right-hand cylinder the second boy catches it and rolls it into blocks of about 50 pounds each; these are now ready to pass to the presses, and any manufacturer who will use these methods will be sure of preparing good terra-cotta clay. The clay having been properly prepared is next moulded or modeled into the required design, and if it be a panel or similar piece of work it is turned out of the mould on to a drying-board to be finished by retouching, undercutting, and drying.

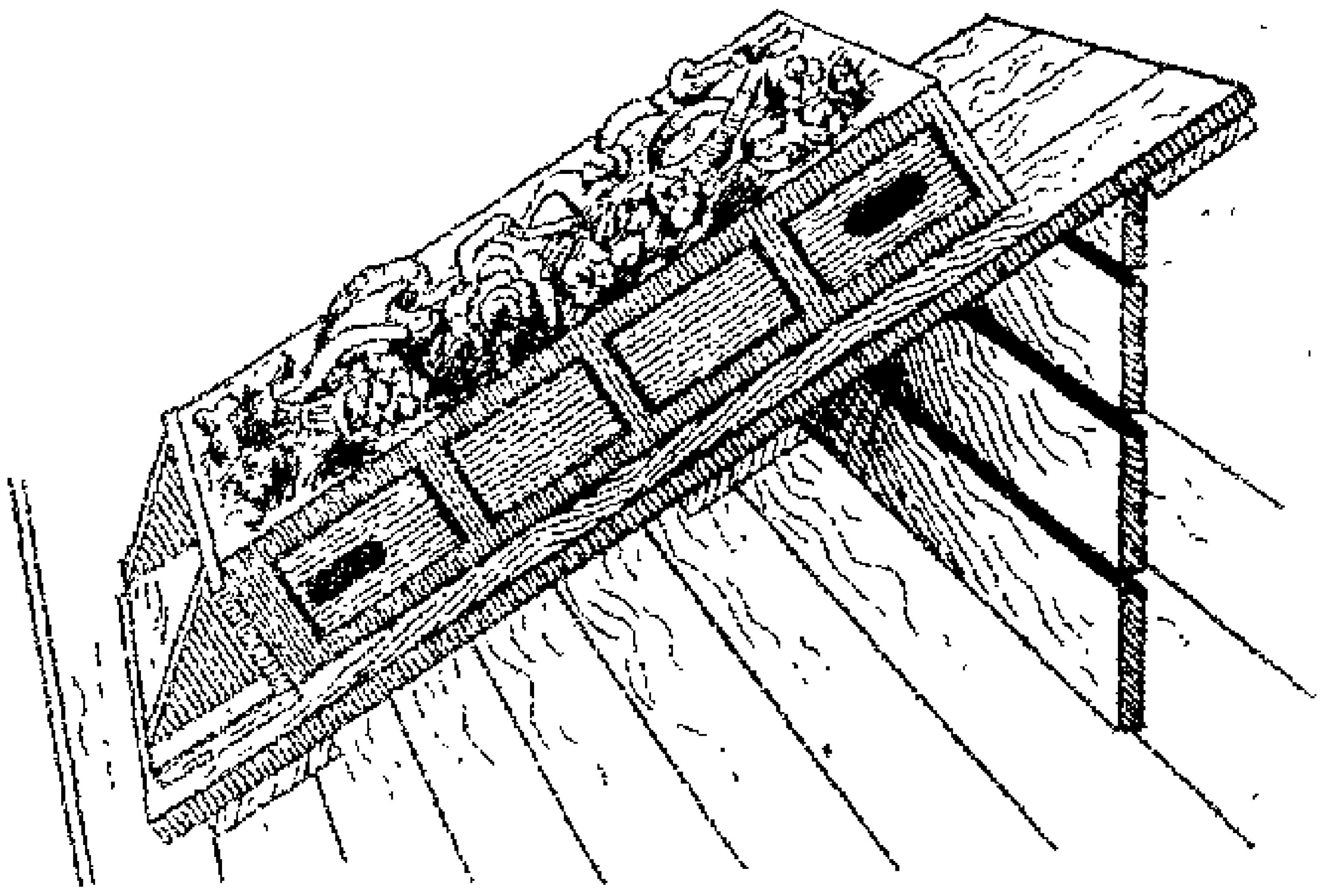
These drying-boards are an important part of the furniture of a terra-cotta factory, and require to be carefully made. They should be strong enough not to bend in the slightest, when being lifted about by the workman, or else the piece of work upon them is liable to get broken by undue strain upon some weak point. They should be made of white pine, as that

wood is the least liable to warp and split under the alternate wetting and extreme drying to which they are subjected while in use.

Drying-boards under two feet long may be made of one inch stock (smaller ones of even less thickness); those under three feet long should be one-and-one-quarter inches thick, those under four feet should be one-and-one-half inches thick, and all over this length should be two inches thick.

When the drying-boards are made of strips six inches wide secured to cleats of the same size, the strips having an open joint three-quarters of an inch, they are less liable to split and warp in use than when wider boards are used; moreover, the open joint permits the air to circulate in the interior of the piece of work, and thus expel the moisture on all sides at once.

FIG. 187.



DRYING TERRA-COTTA.

Figure 187 shows such a piece of work placed upon a drying-board such as has been described, and illustrates a practical method of drying terra-cotta work preparatory for the kilns.

A rough bracket, it will be seen, has been screwed on the lowed end of the drying-board to permit it being placed at a sharp incline without allowing the piece of work to slide off.

This incline is given in order to reduce the friction of the clay upon the drying-board, and thus avoid cracking. It is easy to understand this principle; the clay contracts as it dries, and some clays are not tenacious enough to draw their weight over

so much surface when laid level, but when placed upon an incline, the material naturally falls into its place during the drying process. For large pieces it is advisable to have brackets at both ends and alternate the incline daily; because the lower end has to sustain all the weight, and is apt to crack if not sometimes relieved; also the top end dries quickest, so that the reversing of the ends tends to an equal drying of all the parts.

It is obvious to the most casual observer that a panel of clay-work such as is described above has four corners and four lines of exposed edges. The four corners will dry first because they are exposed to the air on three sides, the upper edges will dry next quickest because they are exposed on two sides, while the top surface will dry slowest of all the exposed parts, because it is only acted upon by the air on one side; moreover, the centre of such a panel will dry more slowly because the moisture is constantly being attracted from the interior. If this panel is placed upon the drying-board and left to dry, it will surely crack unless the clay is very strong, and then it would be likely to warp badly.

The reason for this is very simple, and is in obedience to a natural law.

The clay, when dry, has completed its shrinkage so far as it can do until fired. Therefore as soon as the corners are dry they cease to contract; then the exposed edges still continue to contract, moving most in the direction of the centre, because they dry from the corner toward the centre, the result being that the edges are all curved inward when dry, from the efforts of the mass to contract toward the common centre of the panel.

The edges having completely dried, in turn like the corners cease to recede, but the entire central surface has considerable shrinkage to perform yet, and there is no avoiding it; *until dry it must shrink*, and as the corners and edges, having done their part, have become rigid, the centre can only shrink by breaking loose somewhere, hence the cracks so often found in large pieces of work during the process of drying.

The remedy for this is to guide the elemental movement. It

is possible to direct, even if we cannot oppose, natural forces. By covering the edges and corners of such a panel with a light rubber cloth (which can be bought for twenty-five cents per yard), and leaving about one-third of the upper surface of the centre only exposed, the centre can be made to dry first; then the edges will contract upon the centre, drying from the centre, and the result will be a sound and perfect form. The raising of this drying-board to an incline not only reduces the friction, but it also allows the air to pass freely through the open joints of the drying-board into the cells and back side of the panel, and thus aids in an equable drying of the whole mass. This principle, with modifications to suit the particular shape, weight, and bulk of the pieces being made, will insure success in the making of any piece of clay work that it is practicable to make. Successful drying demands constant watchfulness.

In any factory that employs steam as a motive power for its machinery, steam piping will furnish the best and safest heating for the purpose of warming the shops and drying the work in process of manufacture.

The steam pipes should be hung over head, about one foot below the ceiling or lower edge of the next story floor-beams, and should consist of numerous single lines of one-inch pipe connected with a four-inch header at both inlet and outlet, care being taken to allow ample escape for the exhaust-steam, so as to avoid any back pressure upon the engine.

The pipes should be placed in the second section of beams from the wall, and the floor over the pipes should be laid with open joints of half an inch. This enables the entire section of the floor next the windows to be used for working near the light, and, of course, there the floor is tight-jointed, and should be double with paper between to prevent dust and water leaking through.

The finished work is set on the open-jointed portion of the floor, and is thus in a constant but gentle circulation of air, which enables it to dry equally, and without cracking or warping.

After the work is dry enough, it is moved toward the central

sections of floor, which also is tight-jointed and double, to await its removal to the kilns.

There is no necessity for either steam-pipe heat or open floor in the kiln-end of the building, as it will be found that the kilns themselves, when in constant operation, will ventilate and heat the workshops, and dry the work made in that portion of the factory.

In addition to the above, there should be a circuit of steam piping for live steam, to be used in extreme cold weather only. This should be placed at about seven feet six inches from the floor and three feet from the outer walls, and encircle all the space not warmed by the action of the kiln heat. The position, of course, can be varied to suit any other conditions, but in a building such as is described this would be the method to adopt, and the circuit would be a direct one; the top story only requiring three lines of pipe, the next lower one line of pipe more, and so on until the first floor is reached; this would thus require six lines of pipe, which would give ample heat at a low pressure of steam.

The question of drying the clay forms, after they are taken from the moulds, and preparing them for the kiln, is also one that must be governed by some general rules, but these rules can only be observed subject to the special case of the several forms of clay work produced. It is possible to state some method that will apply generally to the drying of simple forms, such as brick and pottery, which are of universal shape and bulk; but in case of architectural terra-cotta work, which varies so exceedingly in its size, shape, and bulk of material, no specific method can be stated so as to be of universal application.

The rules to be observed are simple and few. First, avoid too violent a draught of air. Second, reduce the friction of drying clay upon the drying board as much as possible, and third, dry uniformly.

Extreme draughts of air cause the external surfaces to dry too rapidly, and the result is warping and cracking. The weight of clay in a piece of terra-cotta work is often greater than the

tenacity of the clay is able to move in proportion to the shrinkage, hence cracks in the weak parts of the form which is being dried.

Unequal drying of the parts also produces warping and cracking.

Suppose a piece of work has to be made three feet long, by two feet wide, and six inches thick: this should be moulded of a uniform thickness of one-and-a-half inches, with cross partitions about six inches apart each way in its interior or back side, such partitions being only one inch in thickness, and care being taken to make a circular hole in each section of the partitions to allow of a free circulation of air among the cells thus formed in the body of the piece of work.

BURNING.

The muffle terra-cotta kilns, as used by the New Jersey companies, are extremely simple in their construction, of which Fig. 188 gives a correct elevation; see also frontispiece.

The kilns are up-draft in principle, and provided with short high furnaces arranged for anthracite coal as fuel. There is a double door, the upper one resting upon piers, thereby forming alleys and flues. In the centre is a communicating chimney that connects with the hollow floor space, carrying heat from the furnace under the floor and up through the center of kiln, whence it escapes through the center hole in main crown into dome, not to be utilized any further.

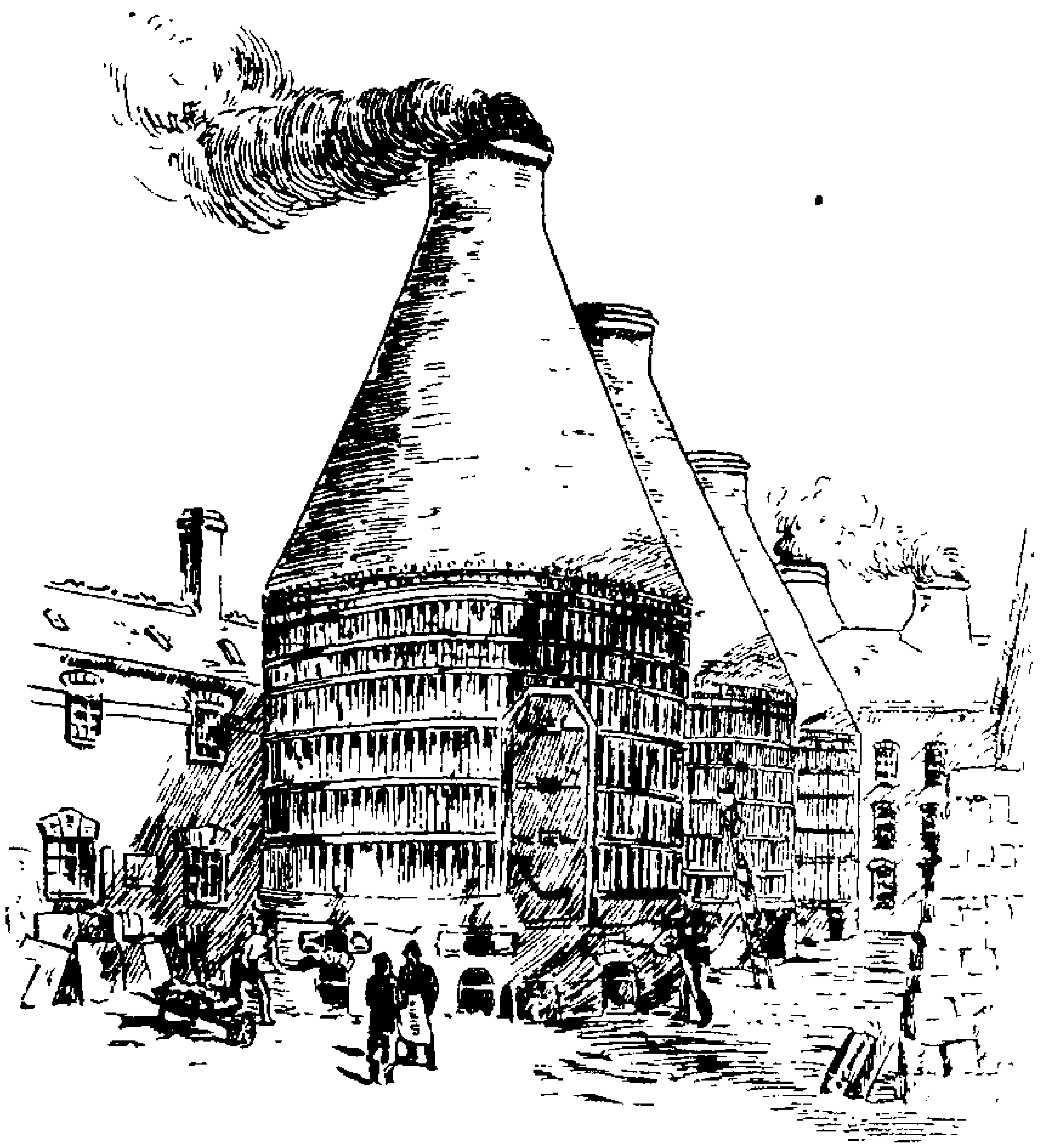
The principal heat rises directly from the furnaces into the flue surrounding the muffle, then under the main crown over the muffle crown to the center outlet into the dome.

The regulation of the heat under the floor and through the center of the kiln is by closing and opening more or less the flue spaces leading from the furnaces to underneath the floor and center chimney. The draft of kiln is effected by regulating the opening in main crown in dome by means of a fire clay tile.

The kilns are invariably round in shape. The inside meas-

urements are 12 feet diameter and 12 and 20 feet high. The muffle flues are 6 inches, muffle tiles being 2½ inches thick. Some of the furnaces have open fires, as shown in Fig. 189, while others are provided with doors, as in Fig. 188. The burning quality of the kilns is good, but they are wasteful of fuel.

FIG. 188.

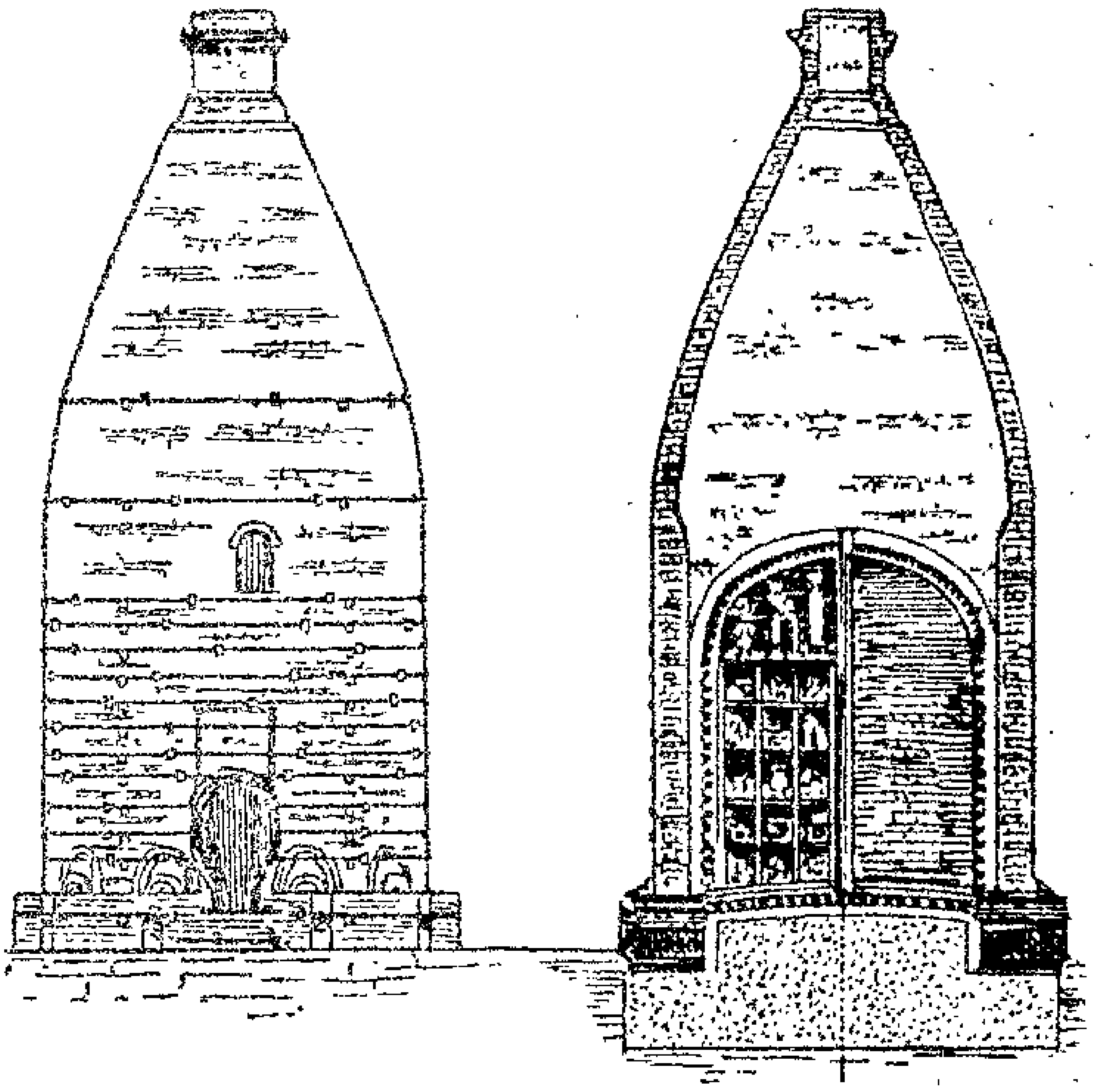


MUFFLE TERRA-COTTA KILN.

The kilns as built by the two works in Boston differ somewhat in construction, as will be seen in elevation and section of Figs. 189 and 190. Some of them are built round and some oblong. Their size varies from 10 to 12 and 13 feet in diameter, by 9 to 17 feet in height. The muffle flues are from 4½ to 5½ inches spacing; thickness of muffle varies from two to three inches. In circulation of heat they are up and down draft: the heat rising upward into the muffle flue, over the muffle crown, and downward through the centre flue (or chimney), then

under the floor, and from there the heat passes upward in flues built between the furnaces in the muffle space, then leads into the dome on side of kiln. The number of furnaces to a kiln are six

FIG. 189. FIG. 190.



TERRA-COTTA KILNS.

and seven. All the kilns are built with projecting top feeders, arranged for anthracite coal, which is being used exclusively as fuel.

These kilns do good work, and are more economical in the consumption of fuel than the direct up-draft as used by the New Jersey companies.

The muffle kilns adopted by western works differ in many ways from those of eastern manufacturers, ranging from 12 to 24 feet in diameter, and from 9 to 22 feet in height, and are, without question, superior to those used in the east.

The Northwestern Terra-Cotta Company of Chicago adopted two styles of muffle kilns—direct down-draft and up-and-down draft. They claim that the latter are giving better results in even burning and a slight saving of fuel. The fuel used is Indiana block coal, also called Brazil block. This coal is very

rich in carbon and very free burning, much resembling Scotch machine coal, except that it is harder and can be cut and split like slate. It makes a clear, mild fire, like that of oak wood. Fuel, of course, has much to do with the good working of a kiln. It is reasonably certain that with an anthracite coal that lies quiet in the furnace, producing a less lively fire, a less perfect circulation or distribution of heat will be effected than by using a coal carrying a decided flame, thereby having a farther calorific effect. Of course, in building kilns, the requirements of mechanical science are far different than for building a brick house. Some masons think that in bricklaying all brick bonds are the same. This may do for the inexperienced, but it can be readily understood that in a wall that is exposed to a continuous action such as expansion and contraction, the wear and tear is very destructive in comparison with the undisturbed masonry in a building of different character and purpose. In a good kiln three qualifications are essential: good combustion, even circulation of heat, and durability of construction. The building of kilns should not be left to inexperienced persons, as they represent the principal part of the capital of a well established works.

One of the hardest colors to obtain uniformity in the tint is the elegant buff, and to secure this rich, pleasing color in terra-cotta, requires long burning, and a highly experimental knowledge of firing, as well as a thorough acquaintance with the clay, and its behavior in the kiln.

FUELS FOR TERRA-COTTA.

Coal should not be used in firing light-colored terra-cotta, as, although the usual products of combustion are separate from the ware, sulphurous fuel darkens and tarnishes the surface. Wood should be used in burning light-colored terra-cotta; but for red or darker-colored ware no objection should be urged against the use of coal.

Kilns for burning terra-cotta are generally circular in form, and are expressly built so as to obtain a greater degree and

better distribution of heat than can possibly be obtained in an ordinary open brick-kiln. A perspective view of terra-cotta kilns is shown in the frontispiece of this volume.

The principle of applying the heat in terra-cotta kilns by the overdraft system is much approved. In these kilns the heat is carried to the top through flues in the walls, and the kiln being covered, and the draft toward the bottom, the heat descends through the ware.

In this class of kilns the stock is not so liable to crack, break, warp, and twist, as in the Hoffman and other annular constructed kilns.

But the principal gain in the circular overdraft kilns is the impartial and equable distribution of heat, thereby securing a greater uniformity in the color of the terra-cotta, which, in addition to the saving mentioned, makes such kilns very desirable.

The usual time required for burning terra-cotta is from five to seven days, which is dependent upon the condition of the ware when it is set into the kiln, as well as upon the purposes for which it is required.

IMPROVEMENT IN THE CONSTRUCTION OF TERRA-COTTA KILNS.

The object of the arrangement shown in Figs. 191 to 193 is to modify the construction of the doors of kilns for burning terra-cotta in such a way that the heat will be distributed equally through the door and the other parts, so that all of the kiln will have a uniform temperature.

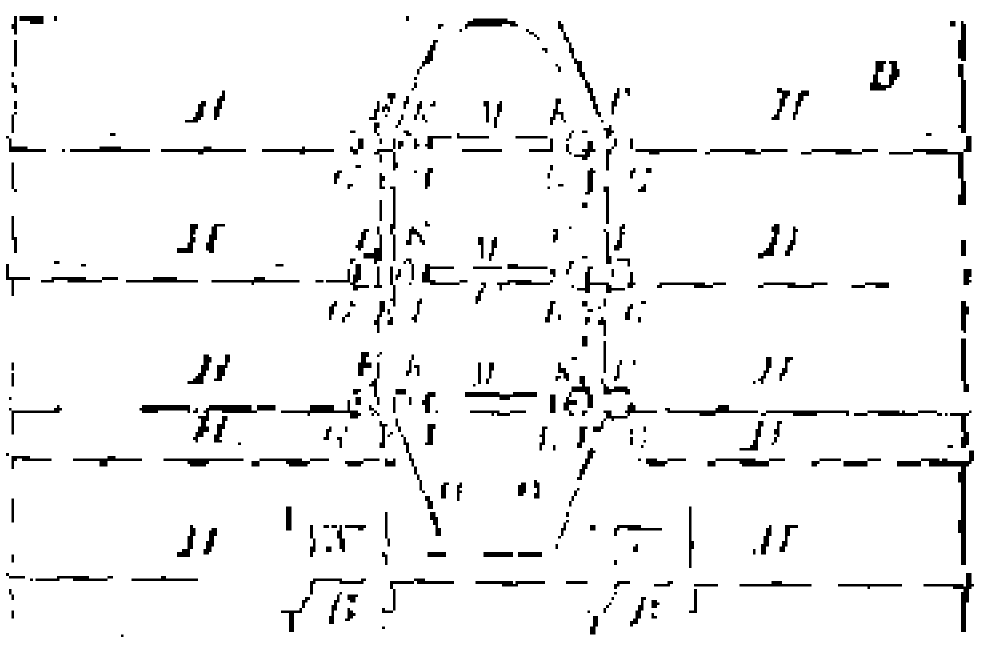
The invention is that of Mr. Afred Hall, of Perth Amboy, N. J., a gentleman who has spent a lifetime in the manufacture of terra-cotta, and it consists in so arranging a door for terra-cotta kilns, with flues in its inner part, communicating with and forming continuations of the ordinary flues in the kiln-wall, and connected with the furnaces by flues, that a uniform distribution of heat all around the kiln will be effected, and all the articles in the kiln will receive an equal degree of heat, and thereby be burned more satisfactorily than is usual.

Fig. 191 is a front elevation of the improvement, shown as

applied to a kiln. Fig. 192 is a sectional plan view of the forward part of the kiln. Fig. 193 is a sectional elevation of the door.

A represents the furnace doors, *B* the ash-pits, and *C* the door of the kiln *D*. To the side parts of the door frame are

Fig. 191.



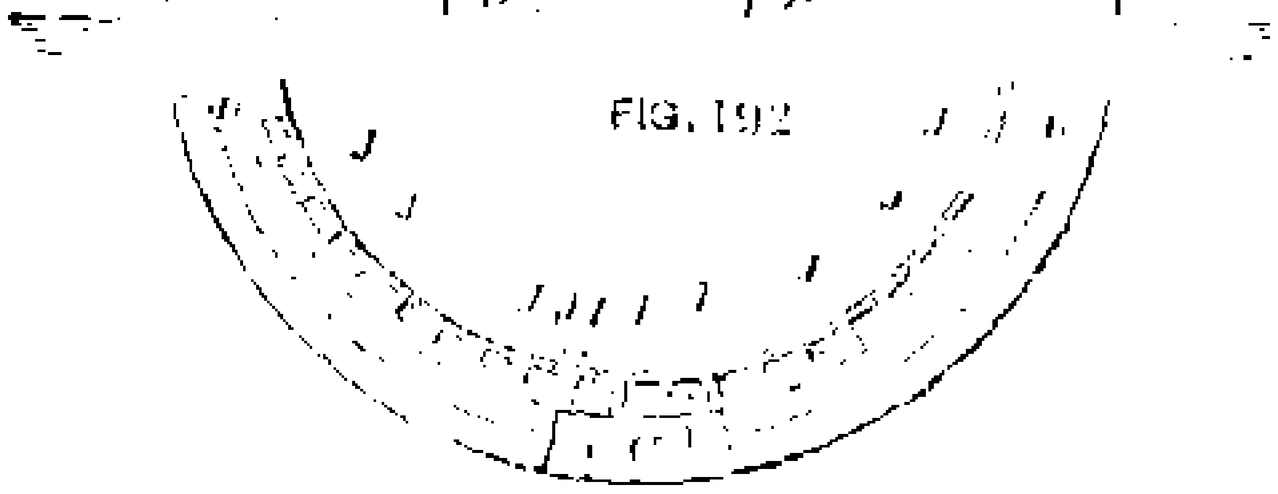


FIG. 192

Fig. 193.

attached plates *E*, which project at the sides of the door, and have eyes formed in their outer ends to receive pins *F*. The pins *F* also pass through holes in the ends of the U bars or clevises *G*, between which ends the eyes of the plates *E* are placed. The bends of the bars *G* pass also through eyes in the forked ends of the right and left screws *L*. The screws *L* pass through right and left screw-holes in the ends of the bars *M*, which cross the door *C*, and have a longitudinal slot formed through them to receive a lever, so that they can be turned to

draw the screws *L* inward and firmly clamp the door *C* in place. With this construction the door *C* can be removed by removing the pins *K*, the screws *L*, and the bars *M*.

In the inner part of the door *C* are formed flues *I*, which, when the door is closed, communicate with and form continuations of the ordinary flues *J* in the inner parts of the kiln walls. With this construction the inner part of the door and the inner wall of the kiln will be heated perfectly, so that there will be no cool part of the kiln, as the products of combustion from the furnaces *A* are introduced into the flues *I* of the door *C* through flues *a* in the same manner as they are introduced into the flues *J* in the inner wall of the kiln, so that the heat will be distributed evenly all around.

MODELING TERRA-COTTA.

Considering the fact that this is a great time for the revival of lost or neglected arts, it is not surprising that modeling of terra-cotta should have been given a high place. It is a kind of work eminently adapted for amateurs, and those who contemplate making a business of clay working, and we do not hesitate to commend it to them, in the belief that faithful and conscientious workers will reap a rich and abundant harvest as the fruit of their labors. In the earliest ages this sort of modeling was much practiced; then came sculpture; but that art depended on modeling, as it does now, for its excellence.

The process of manipulating terra-cotta is not essentially different from that of other clay. Care should be taken in the selection of the model. Bearing in mind that it is easier to copy a large-sized head than a small one, for the reason that the lines of the former are longer, deeper, and require less minute work, the amateur should choose some fair-sized plaster of Paris cast as his first model. Very good specimens can be procured of almost any cast-maker at a low rate. As the worker progresses in the art it will be well to copy works of representative masters, many of which are well worthy of imitation, whether for the excellence of the work, the faithful-

ness of the model, or the patience and scientific knowledge displayed in their construction. From this the transition to copying from life is easy; for, although in the latter work a greater experience in drawing is required, and some familiarity with geometry and anatomy is necessary, it is not so difficult as may be imagined.

The materials are few in number and inexpensive, which latter fact will score a long point in its favor with many amateurs, especially those who undertake the work merely as an experi--ment The material consists of a modeling stool, a hollow flat box, a few boxwood tools of various shapes and sizes, and the terra-cotta clay, which may be obtained ready for use, and which will keep for months.

If the subject be a head, the process is as follows: Take the flat box and screw an upright piece of wood firmly through its middle and let it pass through the hole of the modeling stool that is made to secure it. This will also support the bust while it is in a moist state. The clay is then piled around the wood after having been wetted and well kneaded to prevent it being hempy and streaky, and cracking while it is drying. Work the clay compactly and firmly around the base of the upright first, and then pile it up to the required height of the bust and knead it well with the fingers, which should be kept moist to prevent the clay from sticking to them. The clay will settle and it may possibly fall down after being left, and must be rebuilt, but this little trial will not occur after the second working. Form the clay into the rough form of the bust, and having measured the height and widths of the model, work the clay to match its proportions, using the fingers for the purpose. Then model the features roughly, and block in the hair in broad masses.

This being done, the first day's work is finished and the terra-cotta should be enveloped in a wet cloth, which must be kept moist. This may easily be done by sprinkling it with a florist's syringe, which is a much better plan than removing it. Some judgment is required in this, as, if kept too wet, terra-cotta will

not bear shaping with the fingers and tools, and if allowed to get too dry it will invariably crack and spoil the work.

The second day's work consists in shaping the features, which is best done with a wet rag wrapped around the forefinger. All the features must be gone over and carefully worked up, and the head and hair completely formed, the lines of the hair being finished with the modeling tools. A little terra-cotta clay softened to the consistency of cream will be found useful to apply to any parts that require smoothing.

When the work is finished and nearly hard it should be polished. This is accomplished by taking a piece of fine leather, soaking it in water and rubbing it gently over the bust until the result is attained.

Modeling terra-cotta from the clay is very fascinating work, and not difficult. A fair knowledge of drawing is of course necessary. A good stock of patience and perseverance will also be required to achieve anything like satisfactory results, but the game is worth the candle.

CHAPTER XV.

ORNAMENTAL TILES, ETC.*

SOME years ago a learned Italian found in an old library in the city of Florence a manuscript of the fifteenth century on the Art of Painting, in which the author traces the history of the art back to the common father of mankind, and from Adam to God Himself, thereby seeking to prove that the art was divine and coëval with the very creation of man.

Although we cannot claim so high an origin or go back quite so far with the history of tiles, nevertheless we can positively state with truth that wherever we find historic man we are sure to find tiles of one kind or another. In fact, among the most ancient documents we have, are records kept upon clay tablets, which are nothing more nor less than tile books. I allude to the Chaldean and Assyrian tablets found in such numbers amid the ruins of Mesopotamian palaces, and from which the Assyro-Chaldean student has been able to add many pages to the history of the primitive civilization of man.

That tiles are found so universally under every form of civilization and in every age is not to be wondered at, when we remember that they are made of clay, a substance found in all lands, cheap, plastic in its nature, yielding readily to the hand of man, and becoming fixed by the sun's heat or by fire, and that they lend themselves under their numberless forms not only to many practical ends, but also to the highest requirements of decorative art. So we find tiles used as records, floors, walls, roofs, ceilings, tombs, baths, altars, pulpits, altar pieces,

* Partly from an article by Caryl Coleman published in the Decorator and Furnisher New York.

friezes, dados, fire-places, hearths, wainscots, table tops, drains, stoves, grills, balconies, and in many other ways.

The higher the art culture of a people, the greater their use of tiles. For this reason we hear so often now-a-days about tile, when so much thought is given to the decorative arts and cultivation of artistic taste. A few years ago they were almost unknown in the United States, while to-day there are many tile makers and thousands of dollars invested in the business, and yet the demand is greater than the supply both for domestic and imported goods; therefore it seems to me it is high time that the general public should be made acquainted with the history of tile and its use in the past as a decorative medium.

The first thought or question that naturally arises is: What is a tile? To get a true definition we must first consider the origin of the English word "tile." It is derived from the Latin noun *tegula*, and that is formed from the verb *tegere*, to cover, and was used by the Romans to name a piece of baked or dried clay used for covering houses; hence a tile is all forms of baked clay, glazed or unglazed, plain or decorated, which is used to cover, or is applied upon another body or object such as a roof, a floor, or wall, etc. Before 1840 all tiles were plastic, being made from wet clay; since that date the larger part have been made from clay reduced to dust and formed into a tile by pressure.

There are two great families of tiles, unglazed and glazed. The unglazed are subdivided into:

Plain, a bisque tile of one color.

Inlaid, a tile where one colored clay is forced into another color.

Indented, a tile with the designs depressed below the face.

Relief, a tile with a design standing above the face.

Printed, a tile with a design printed in color upon its face.

Glazed tiles are divided in their turn as follows: vitreous or glass-glazed, plumbeous or lead-glazed, stanniferous or tin-glazed, and are again subdivided into:

Plain, a tile faced with a transparent glaze and depending for its color on the bisque or body showing through the glaze.

Enameled, a tile having the face covered with a colored glaze.

Incised, a tile with a design cut through the glaze down to the body or bisque.

Indented, a tile with a design scratched or stamped upon the clay body and covered with a glaze.

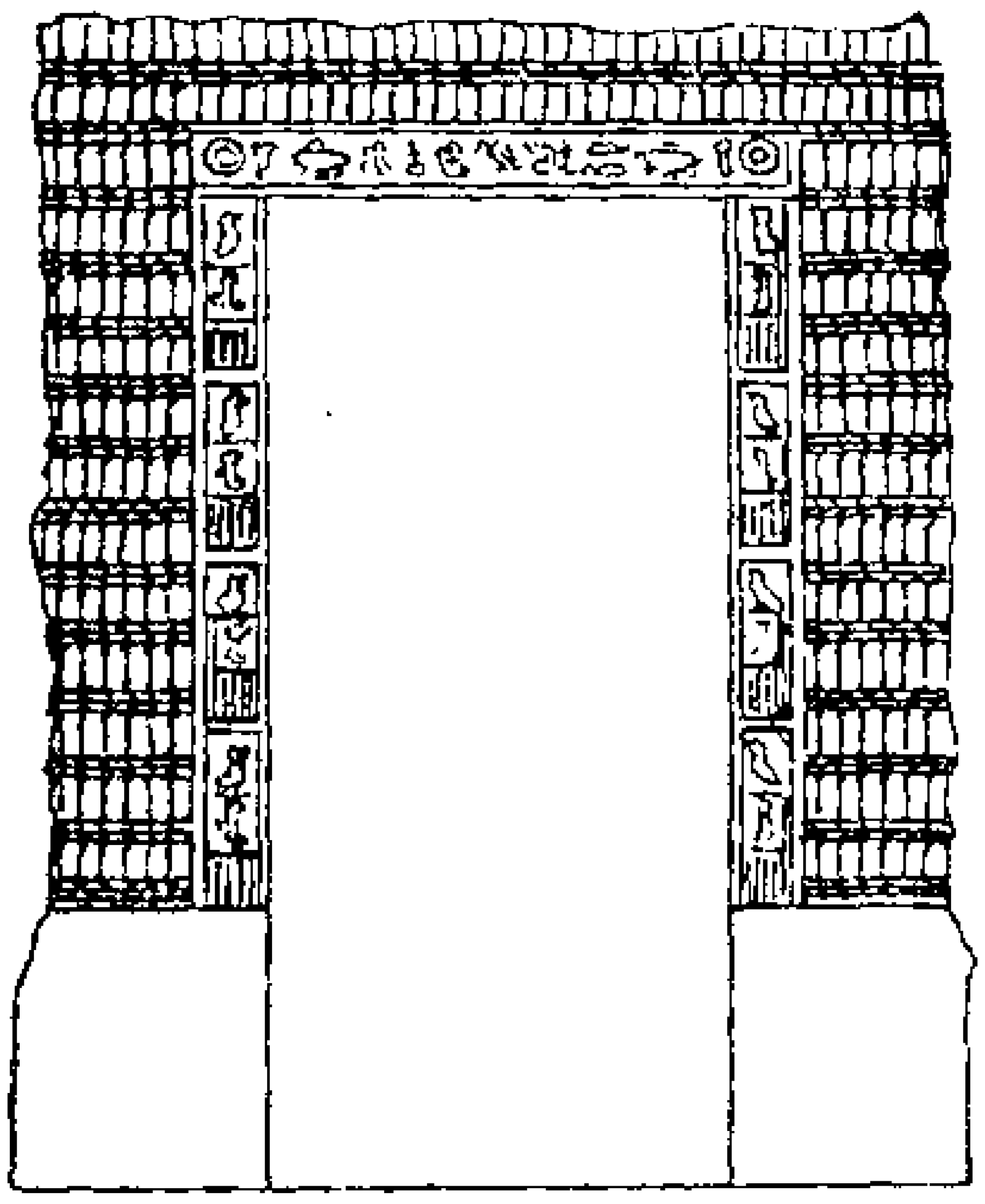
Relief, a tile with a design modeled, pressed, or stamped above the face or back-ground and covered with a glaze.

Painted, a tile with a design painted upon the bisque and then glazed, or a tile with the painting upon the glaze itself. In the first case called underglaze, and in the last overglaze work.

Printed, a tile with a design printed on the bisque and then glazed.

The oldest tile makers that we have any historical knowledge of were unquestionably the Egyptians, who not only made tiles to decorate their buildings with, but also for inlaying wood and bronze objects; however, as with us, their greater use was in architecture, in cases whese beauty of decoration was required.

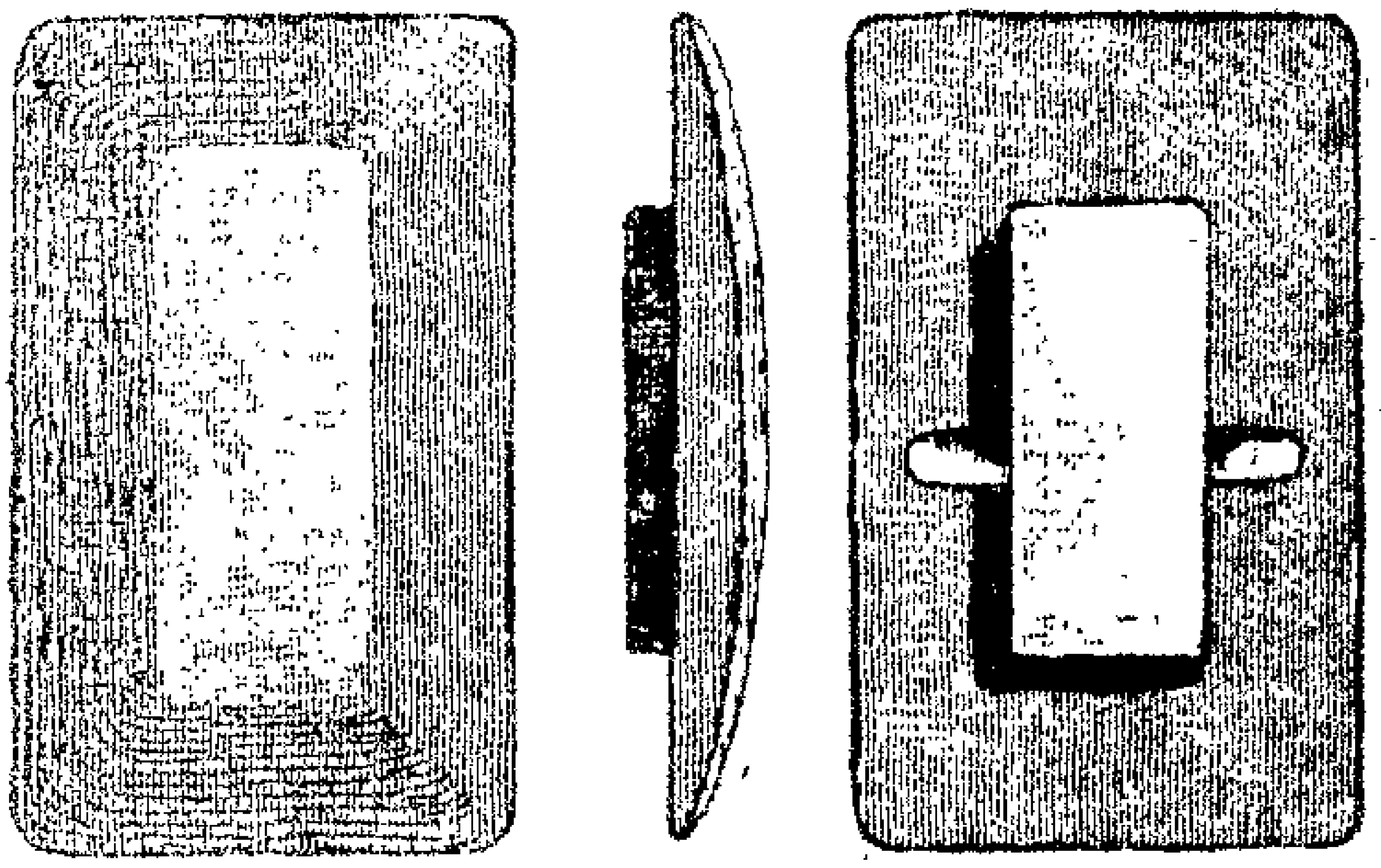
FIG. 194.



This latter application of tiles, with the Egyptians, commenced at a very early period in their history. The inner doorway (Fig. 194) of the pyramid at Laggara was covered with glazed tile of a most beautiful blue, the face slightly convexed, and

having on the back a pierced tenon (Fig. 195). The color of these tile is truly remarkable, a most delicate celestial blue

FIG. 195.



glaze, obtained from a pure and very white sand, soda, and the oxide of copper.

In the brick temple of Ramses III., built 1228 years before the Christian era, tiles were used in great numbers on the walls and floors, around the doorways, and upon the outer walls.

FIG. 196.

Some of the tiles were in relief, the body or background in blue or yellow bisque, with figures modeled upon it in colored pastes,

the garments on the figures of the men in various flat colors, the faces, limbs and hair glazed in appropriate tints (Figs. 196, 196 A, 196 B). The Egyptians, in common with Assyrians, used round inlaid vitrified tiles of white on blue, or the reverse, for the ornamentation of walls (Fig. 197), sometimes massed together, but oftener as string courses and for giving a riveted effect to their walls. Like the Assyrians, but not so generally, they wrote upon tile tablets, not by incising the characters upon an unglazed tile, but like the modern Chinese school-boy writes

FIG. 196 A.

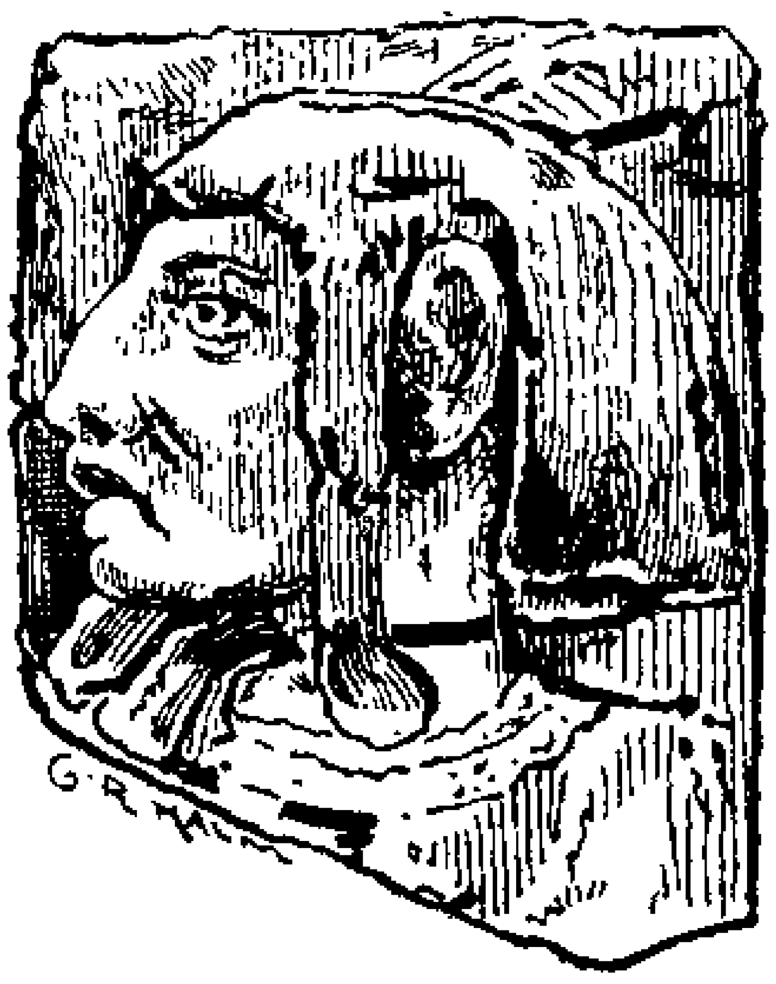


FIG. 196 B.

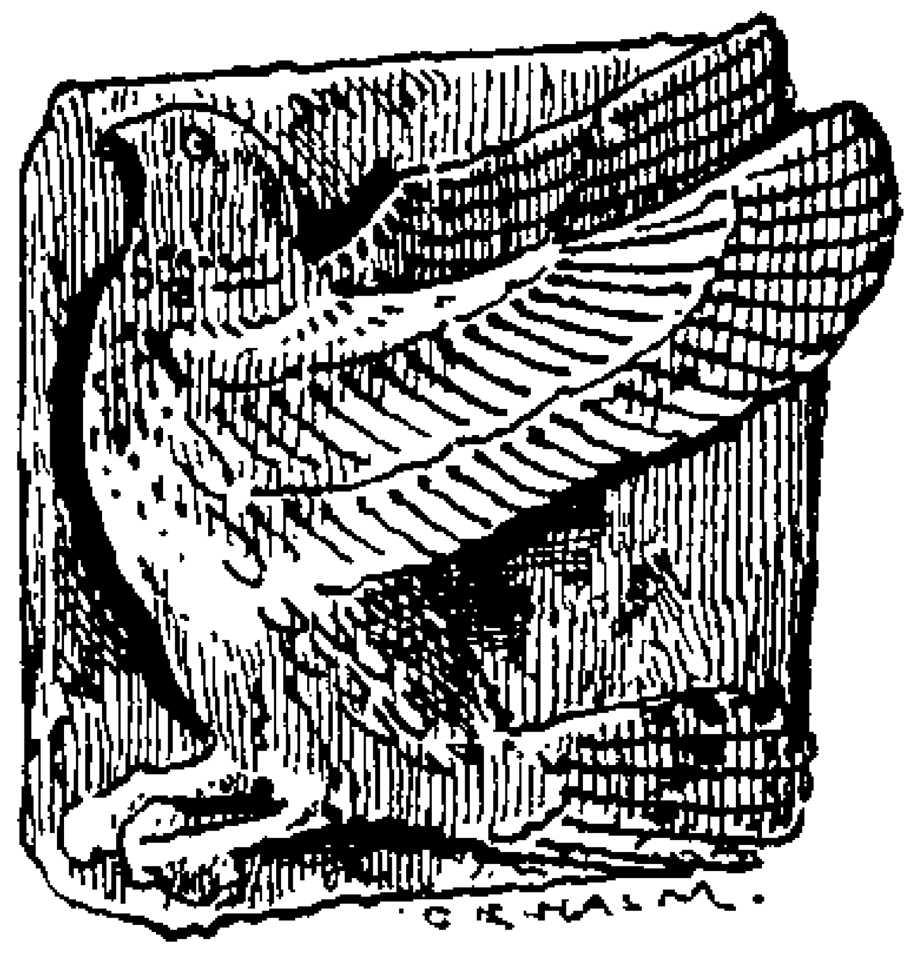
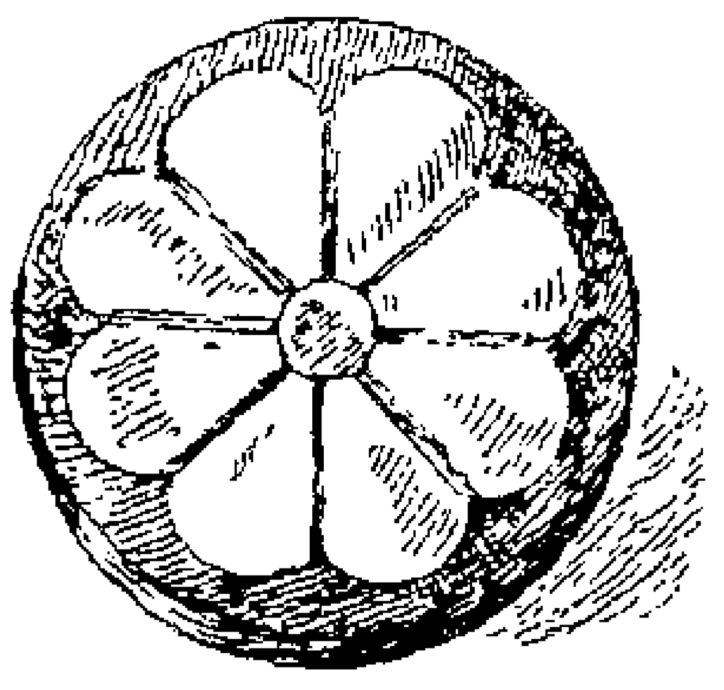


FIG. 197.



them with black ink. That the Jews used tiles for the same purpose we know from the words of the prophet Ezekiel iv. 1:

"And thou, O son of man, take thee a tile and lay it before thee, and draw upon it the plan of the city of Jerusalem."

The Babylonians and Assyrians carried the art of tile making and their application both for practical and artistic purposes, to a much higher point than the Egyptians, and in fact than any other of the ancient nations.

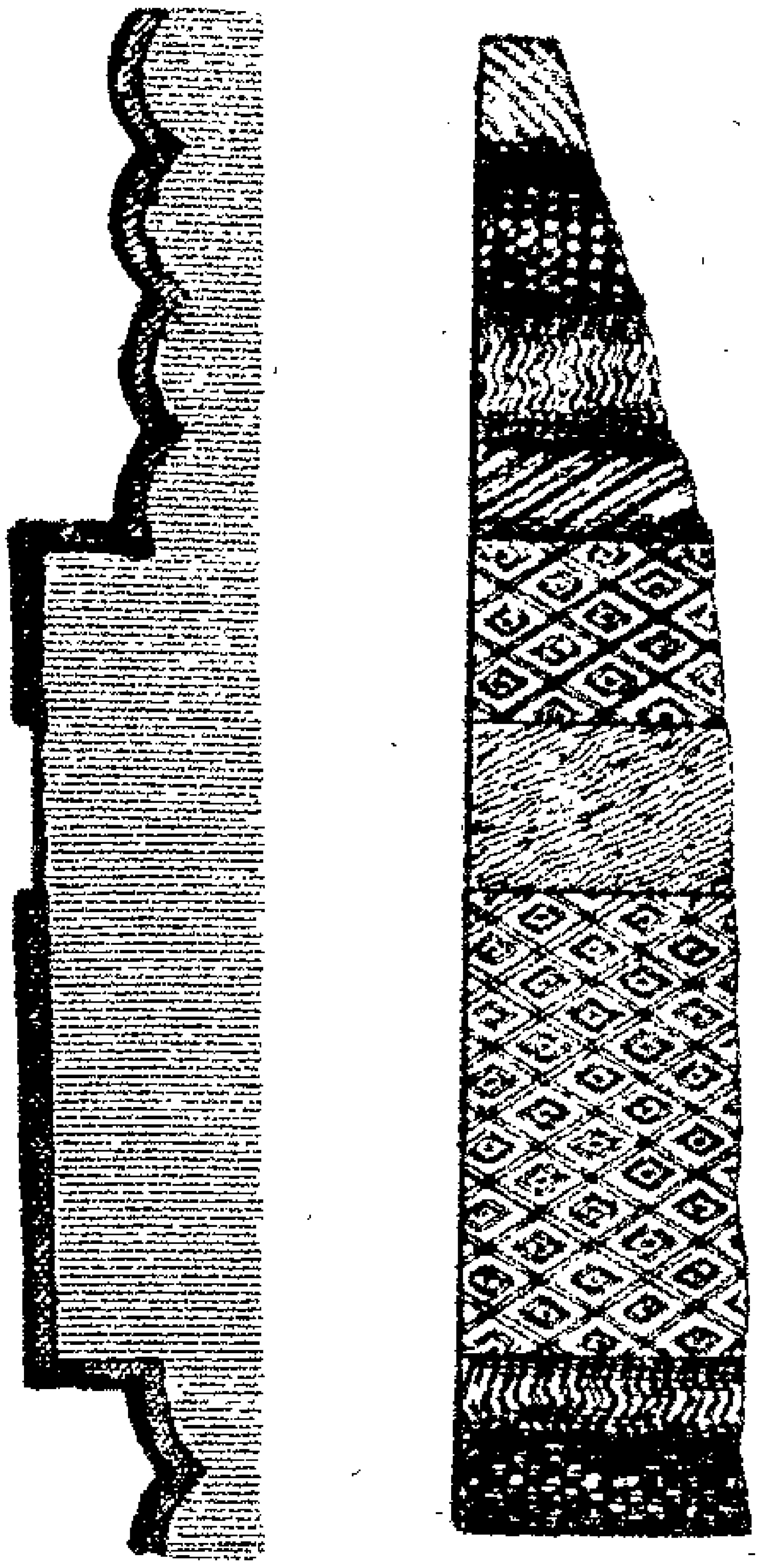
Their glazes are brighter and finer, their range of color greater, and their forms more numerous. One of their most novel forms was a cone-shaped tile, three and a half inches long, of a yellow body, having its base dipped in color and its apex running to a sharp point (Fig. 198). These tiles were not only fixed to flat walls, but also to curved surfaces,

the apex being imbedded in cement, the colored base turned outward and arranged in patterns of various designs (Fig. 199).

The tiles of Chaldea were in part bas-relief, obtained by piling on the color or enamel, while on the other hand the Assyrian tiles were flat, with the single exception of their round tiles, which were used in vast numbers about doorways and the

FIG. 198.

FIG. 199.



upper parts of walls, the central boss being in low relief (Fig. 200).

In Assyria, pictures and geometric designs of large size were executed upon the walls of temples and palaces by uniting tiles, on each of which a portion of the general pattern was made (Fig. 201). The ceiling tiles were of diverse forms—round, square, square with concave edges—but in all cases having a round hole in the center, through which a pin or boss of metal or ivory could be passed to hold them securely in their place (Fig. 202).

The prevailing colors in the glaze tiles were blue, red, a deep yellow, white, green, black, gold and silver, while the unglazed or floor tiles were but of two colors, a dark red and a yellowish white.

The extreme gorgeousness of the tile-incrusted buildings of

FIG. 200.

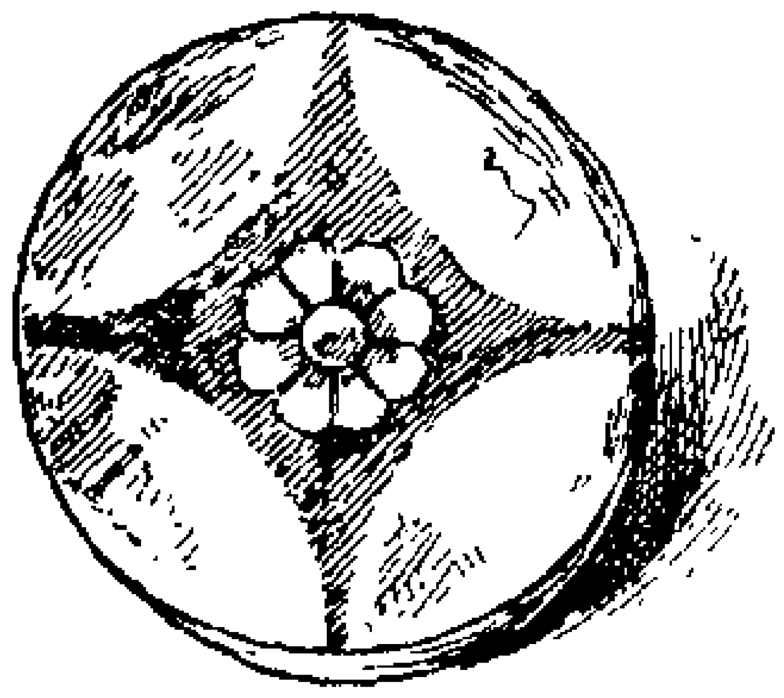


FIG. 201.

Assyria, as they flashed forth their beauty under a brilliant oriental sun, is hard to picture to our minds, accustomed as we are to the colorless architecture of the present day. Is there not a lesson to be learned here? Should we not be more bold in our use of color, not only for interior but also for exterior decoration? No doubt color will be used more freely among us when our architects are properly educated, when they become not only good constructors but have also a knowledge of artistic proportion, harmony of design, and the decorative principle governing the use of materials in their relations of color and texture to the whole structure and to one another.

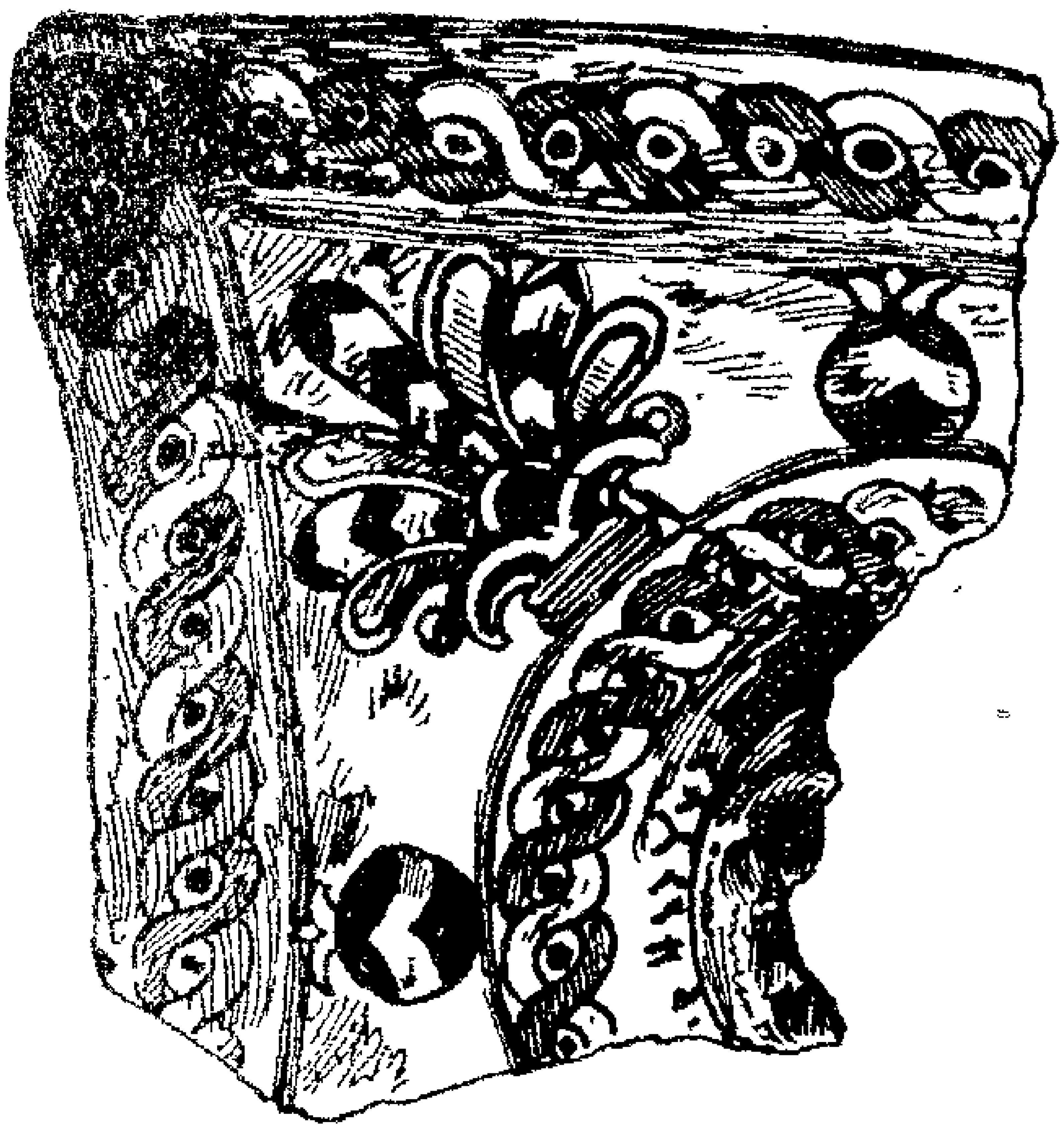
Among the practical uses that tiles were put to in Babylonia (626 B. C. to 522 B. C.) was that of a circulating medium. The

tiles used were four and a half inches in length by one to three inches in breadth, with their value in gold or silver, the name of the reigning king, and the date of issue inscribed on their face.

Very little is known about the tiles of the Jews and Phœnicians—so little, that some archæologists have doubted if these people used them to any great extent.

Among the Greeks tiles were used in large numbers, that is,

FIG. 202.



the unglazed kind, for tombs, for roofs and floors, pediments and friezes; as to their glazed tiles we know little or nothing. How far they carried the art of tile making it is hard to say, although we know from their writers and the examples of their other pottery that they must have attained a high standard.

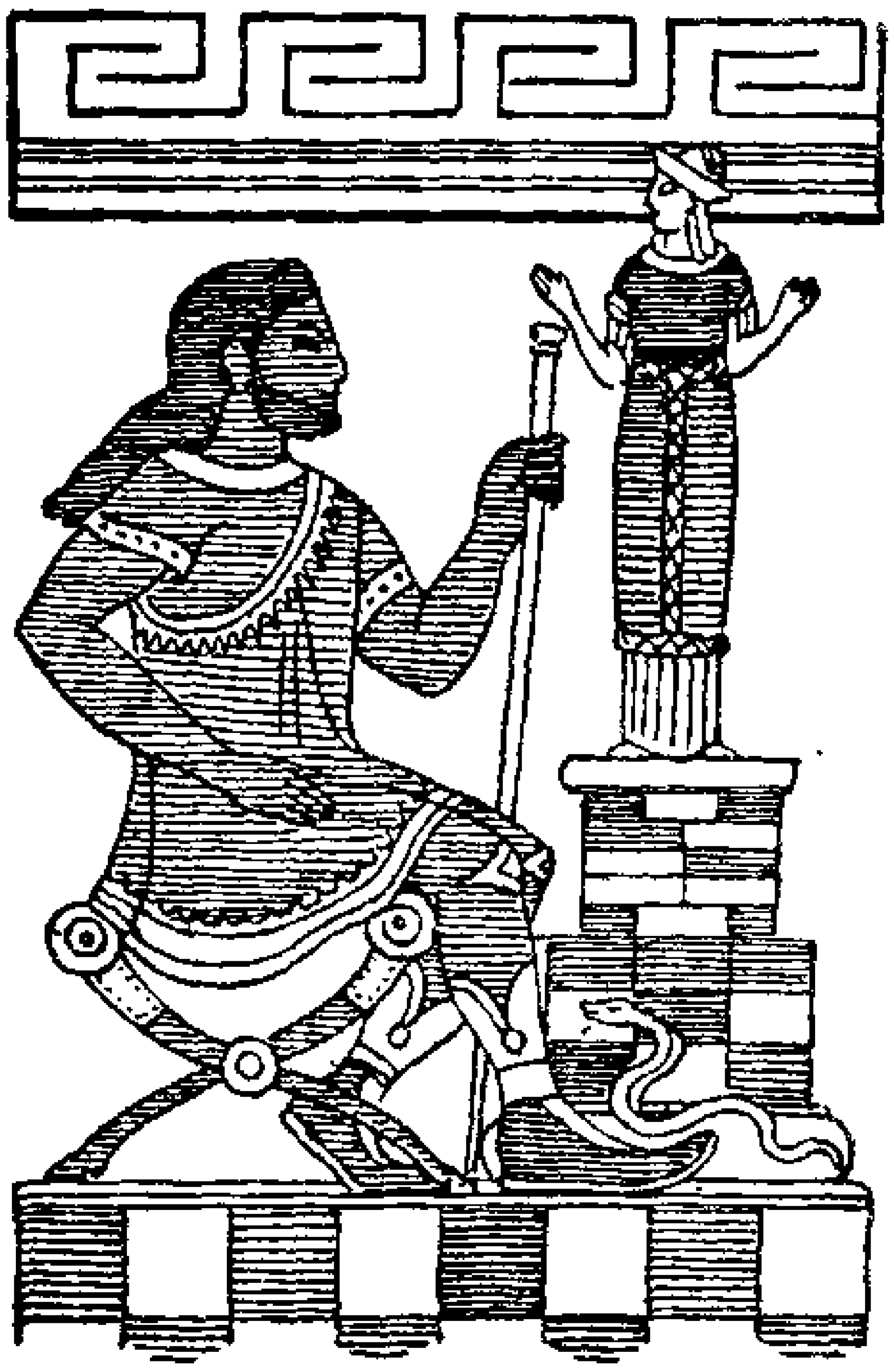
With the Etruscans tiles were principally used to line the walls of tombs. The tiles were large, forty inches long and twenty inches wide, with figures and inscriptions painted on them in red, black and white, and burnt in the tile (See Fig. 203).

The Romans inherited the art of tile making from their

Etruscan forefathers, and also used them as they did for tombs, but more commonly on the walls and roofs of their houses; these tiles were sometimes scale-shaped, sometimes oblong, oftener flanged; in color they were of a rich red and bright yellow. The floor tiles were made in small cubes of various colors and were set in patterns.

With the fall of the Roman empire, the art of tile making, like all other arts, passed under a cloud, but only for a while,

FIG. 203.



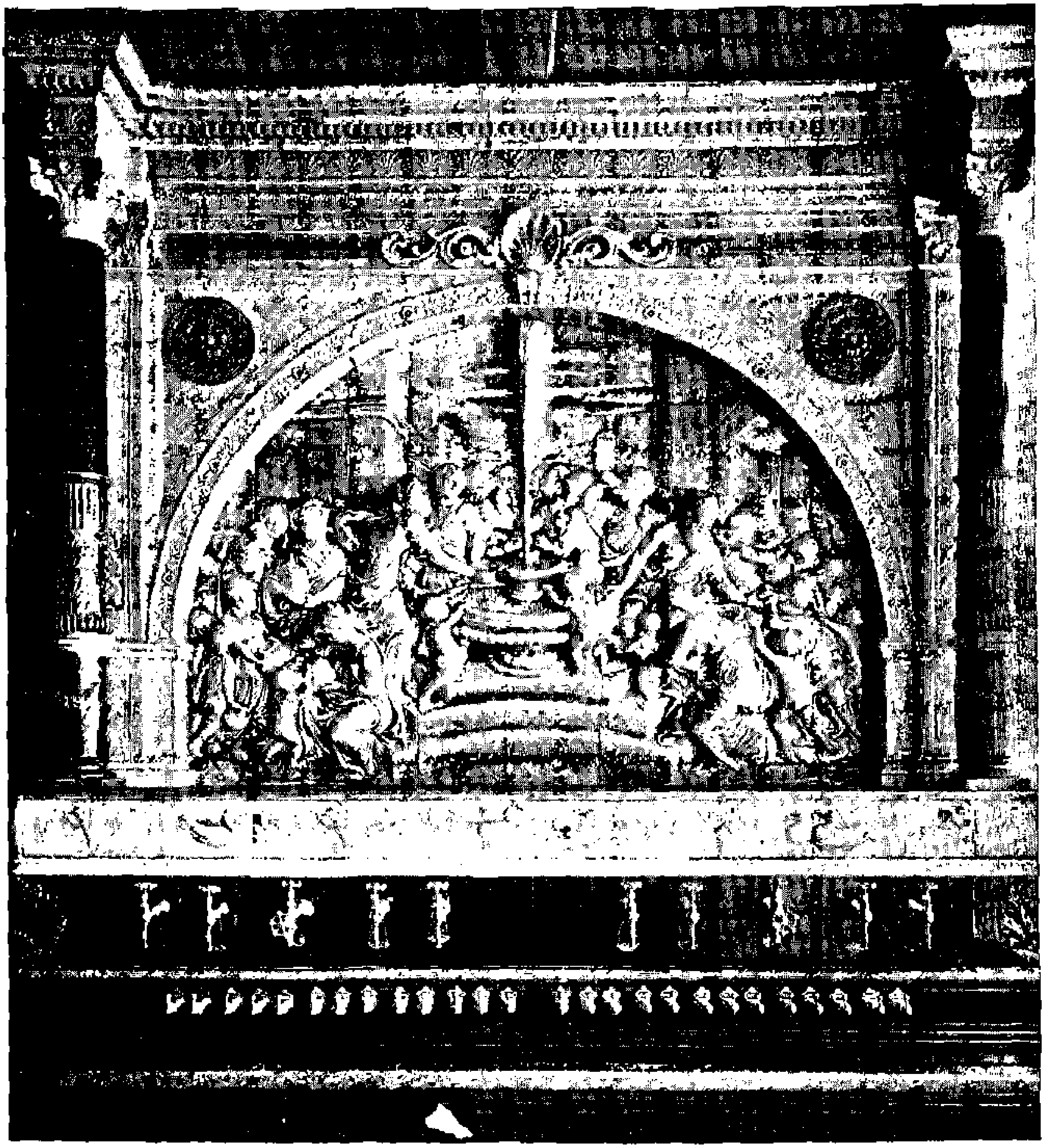
for it was brought to life again by the Mohammedans in the East and the Monks in the West, to shine with greater splendor than ever before.

The development of tile making in the United States has been the most remarkable instance of rapid progress of an industry of any country or age, and our tile makers may be relied upon to hold the place they have gained against all the competition of Europe.

Scarcely two years after the Centennial Exposition, Mr. John G. Low, of Chelsea, Mass., commenced the erection of a tile factory in his native place. Less than a year and a half after

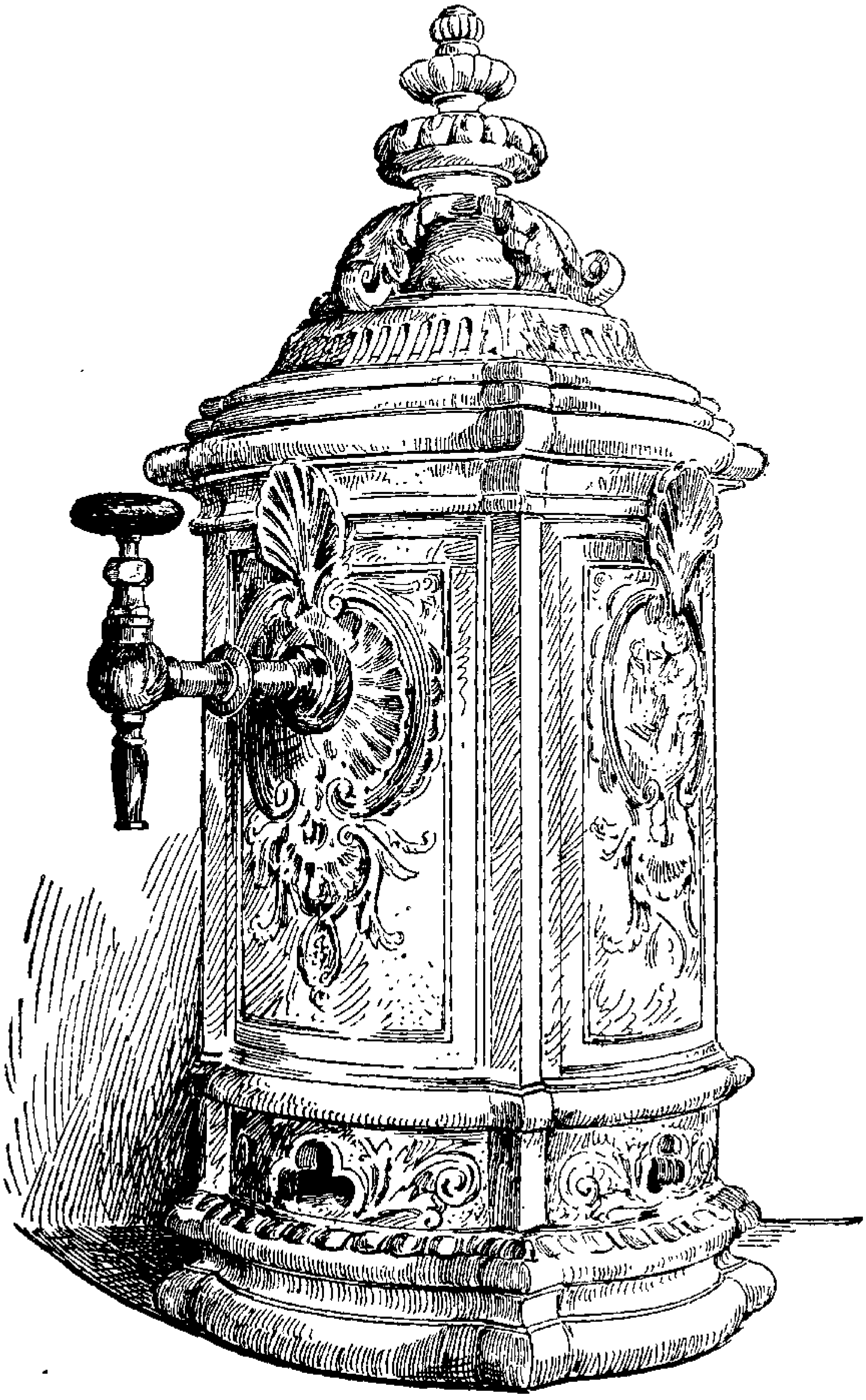
the works were started we find the firm competing with English tile makers at the exhibition at Crewe, which was conducted under the auspices of the Royal Manchester, Liverpool, and

FIG. 204.



North Lancaster Agricultural Society. They won the gold medal for the best collection of art tiles exhibited. This record serves to illustrate the remarkably rapid development of an in-

FIG. 205.



dustry new in America, but old in the East, and shows the resources at command of the American potter.

In 1883, Mr. John F. Low, son of the founder, became associated with his father under the style of J. G. & J. F. Low.

These works make stove tiles, calendar tiles, clothes-hooks, paper-weights, inkstands, and pitchers in plain colors, enameled and glazed. Lately they have been making a specialty of the manufacture of art-tile soda fountains, specimens of which are shown in Figs. 204 and 205.

The Beaver Falls Art Tile Company, Limited, of Beaver Falls, Pa.; the Providential Tile Works, Trenton, N. J.; the Trent Tile Company, Trenton, N. J.; the Cambridge Art Tile Works, Covington, Ky.; and the Menlo Park Ceramic Works, Menlo Park, N. J., are also engaged in the manufacture of art tiles.

In the production of printed, inlaid, and relief tiles, America has advanced rapidly, but in the production of hand-painted art tiles she is as yet deficient. This is a branch of the art that must be developed through the influence of our mechanical art schools, which are paving the way for an early revolution in ceramic industry in the United States.

Our designers saw much at the Columbian Exposition in 1893 to start them to thinking, and when the present industrial depression shall have passed away there will be brought out many new and artistic designs in art tiles.

The process of creating from clay those exquisite creations in decorative design known as art tiles was explained to me by Mr. Lawshe. The tile factory is on the outskirts of Trenton, N. J.

Mr. Lawshe conducted me to the yard, where a lot of cars stood on a railroad track loaded with creamy-colored clay or chalk. It was dumped by a couple of chalk-begrimed workmen into big sheds not unlike coal bins, only much larger.

"This is where the first step toward making tiles is taken," said my conductor. "The chalk is in this box; it is called spar. This is nothing more or less than flint (taking up a handful of powered stuff from another compartment). Just hard flint rock ground to a powder. This chalk and flint, which come from Great Britain, Maine, Virginia and Tennessee, are mixed in proper proportions and dumped into the mill, where it is ground up and run through a series of sieves to extract all grit and foreign substances."

Following the directions of Mr. Lawshe, the writer observed that from the mill, which looks like a big grist mill seen in flouring mills, only larger, the material was conveyed to an enormous vat, where it was mixed with Delaware river water until it assumed the consistency of a big caldron of the Irish national dish, "stir-about."

From this vat the stir-about was quickly pumped into a series of wooden molds about six feet long and two feet deep. Each mold held a heavy duck bag which exactly fitted its inside, through which the water and the stir-about would seep, while the immense hydraulic pressure was exerted to bring them together and the water was all squeezed out. Releasing the molds, they were laid flat-wise and open. The bags were deftly turned back, exposing to view a six-foot section of chalk which looked just like a big apple dumpling after being "undressed" and ready to be placed on the table piping hot. Really it looked appetizing, but the old-fashioned boat of brandy sauce, which our grandmothers knew so well how to make, was missing. The two workmen looked like fat, well-fed cooks themselves. The dumpling was seized and quickly rolled into a big cruller, with the jelly left out, of course, and thrown into a long drying trough, whence, after becoming dry, it was conveyed into the main building and broken into small bits, this time, strangely enough, assuming the appearance of a big pile of broken stale bread.

This stale bread or "wad," was next run through another mill, and still another. From the last mill the wad came out as fine and free from grit as a box of lady's toilet powder, and dry as a bone. An endless elevator, with ever-moving cups, caught the powder up as it fell from the hopper and lifted it to the next floor above, where it lay in bins ready to be pressed into tiles.

Following our pudding, not up the elevator but the more convenient stairway, my conductor halted me by a heavy stamping machine, operated by a red-cheeked youth of eighteen years, who was deftly scraping and putting little piles of the

now slightly dampened powder into a mortise let into the steel bed of the machine. This machine looks like ordinary stamping machines used in notaries' offices, only about a hundred times bigger. The mortise which the youth was filling was about nine inches square and seemingly two or three inches deep. Filling it to the level, he knocked off the superfluous chalk and touched a pulley that set the machine in motion. Slowly, slowly, a massive ponderous rod of burnished steel began to descend, and the powder was crushed into a solid cake of clay by a pressure of eighty tons. Then the bar shot back and became stationary, while the young man handed the writer the newly made tile to inspect. On the reverse side was the trade mark of the maker, while on the face was a clear and beautifully executed profile of Editor Stearns, of the *American Artisan*. It was an exact counterfeit of that gentleman in plaster cast—a bas-relief. The process is just the same as is followed in stamping gold eagles in the mint, and the young man at the machine turned out the counterfeits faster than the writer could lay them in a neat pile.

At another machine a pretty young woman with rich ripe lips and suggestively plump arms, was manufacturing fac-similes of a maiden twenty-four inches long, whose brevity of drapery, if anything which does not exist may possess "brevity," would make "Iza" Johnstone turn green with envy and send Anthony Comstock scooting off to get an injunction and a piece of gauze.

From the stamping-room my conductor led me to the die-room, where all the dies for the myriad of exquisite decorative tiles are taken. All these dies are cut intaglio, and the most expert workmanship is required. The workmen receive high wages and their hours of labor are short.

The modeling-room was next visited and the writer was introduced to Mr. Wm. W. Gallimore, the father of American Belleek ware, the finest and most expensive porcelain in the world. Mr. Gallimore extended his left hand.

"You must excuse his left hand," said Mr. Lawshe, "he has only one."

"Your loss does not seem to interfere with you much," I ventured.

"No, I do not miss it much now. But let me show you how a model is made," and picking up a nine-inch-square block of what looked like plaster-of-Paris, he began laying on little pieces of dirty dough. While thus engaged he continued chatting, occasionally looking up at the writer. Now and then he would pinch the dough up in one place with his finger or press it down in another with a little steel instrument which he held between his fingers.

"Just stand there; that's right; don't move your head now," and with a satisfied smile he went on with his pinching and flattening out process until I saw a reproduction of myself.

Thus mollified, I was led to the dipping room (that's my term for it), where a score of pretty girls, with sleeves rolled up, were dipping the faces of the pressed tiles into pans of what looked like colored milk. One saucy-looking miss was having lots of fun ducking a famous Egyptian Queen into a pan of chocolate-colored milk and laying her side by side on a shallow vessel to dry. Another motherly-looking woman with soft expressive eyes and gray hair, was, with genuine tenderness, giving a sweet-faced little cherub of 10 years a bath in pink milk; while a dashing-looking Irish girl, with a roguish brogue, was sousing jolly old Bacchus deep into a bowl of mixed ale and porter, which the old fellow seemed to like immensely. He was unable to consume it all, however, and it trickled down his abundant beard upon his capacious chest.

Still further on a girl of eighteen was daintily dabbing the smooth faces of her tiles with several different colors, transforming some into chalcedony, others into onyx, both Californian and Mexican, marble and granite, and other handsome stone effects. Only they did not look like these things just then. This was the glazing room, and the milk-pans contained liquid glass into which different chemicals had been stirred to produce the variety of colors required. The girls worked rapidly, and as fast as the tiles were dipped they were borne in the direction

of the furnaces, where they were submitted to the process known as "firing."

This is almost the last stage in the manufacture of a tile, though one of the most delicate, and in some respects the least understood. The tiles are placed in large porous earthen vessels, called setters among the potters who make pots and cups. The setter is filled with tiles and a lid placed on it. Then a piece of common red Jersey clay two feet long is used to hermetically seal the setters. The setters are then placed in the kiln, one on top of another, from the floor to the ceiling. The door of the kiln is then closed and the fires are started. Care must be taken to lay the tiles perfectly level in the setters, and also to make a similar disposition of the setters in the kiln. A perfect disposition of the "glost" on the face of the tile can only be secured thus: Should a tile tip the slightest portion of a degree the lower edge will, after "firing," be found to be much darker than the upper edge, which will be very light. This is due to the law of nature which causes the liquid glaze to seek its level. If one will take the trouble to examine a handsome tile panel, say of a pastoral scene, it will be observed that the sheep in the foreground, standing out almost white, are in bas-relief, while those dark ones on the brow of the distant hill are intaglio. The dark shades surrounding the young shepherd—himself almost pure white—are simply slight concavities into which the glaze, liquefied by the heat, has flowed. In a word, no artist is required to produce the exquisite shading so often met with in the higher class of tiles—you lay on the colors, the fire does the rest.

From the kiln the product is ready to go to the packing room, where all imperfect pieces are rejected, and the different styles are assorted and packed in barrels ready for shipping.

The manufacture of tiles in this country was an unknown industry thirty years ago. To-day nine-tenths of the tiles used in America are made in Trenton and Cincinnati. The art of making tile 24 to 30 inches long and 6 to 15 inches wide in one solid piece, is a New Jersey discovery which foreign makers

cannot imitate. The advantage of this is apparent in inspecting the panels, one made in a solid piece and the other in two or three sections. The glaze on the solid panel will be found all of one shade; but let the maker of the three section panel be never so careful, he will never succeed in producing an exact similarity of shades on the three pieces. The effect of this is less harmonious than the single piece. When Europe furnished all the tiles used in this country, Americans paid $1,250 per thousand feet for the plainest tile, and much larger prices for the artistic panels. Now $250 to $350 is the price for the plain product, while artistic patterns are proportionately low.

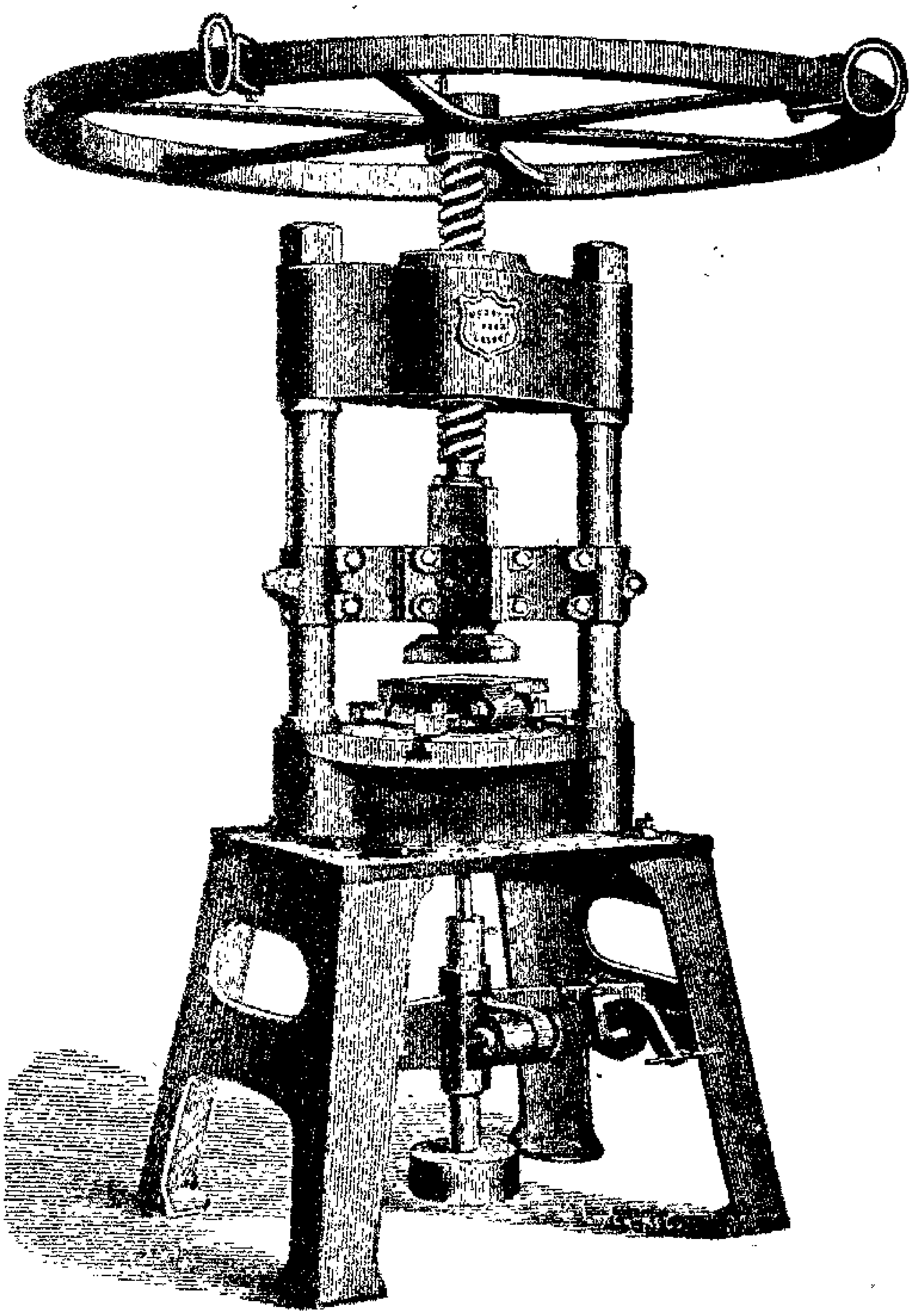
It may be a matter of interest to readers to know that one of the most valuable discoveries ever patented for making patent tiles is the property of a bright young woman, Miss Frye, a school teacher, who will soon be able to desert the school-room and live on the royalty of her patent. Just what this patent is the writer is not at liberty to tell, but like everything truly feminine, it is lovely and simple. It is something every male potter has been trying to discover for many years—a lost art in fact—and every blessed man who has seen it has, man-like, exclaimed: "What a blankety idiot I was not to have thought of it." You see, the only thing to do was to think of it; the balance was easy enough. However, nobody ever thought of it till Miss Frye had the patent safe in her pocket, and along with it a handsome fortune in prospect and a competency for the present. Like all really studious and thinking women, Miss Frye is modest to a degree, and reticent as to herself and her discovery.

There is also a fortune awaiting the man who will rediscover the lost art of producing the green, blue and red of the ancients from copper; the first two colors can be got easily enough, but the last is delusive. Will the "man" who finds this be a "woman" also?

Various tile machines have been designed for the manufacture of tiles from dust or semi-dry clay, but we are unable here to reproduce more than one. Fig. 206 shows a screw press,

made by Mr. Peter Wilkes, of Trenton, N. J., for the Trent Tile Company, and will give an excellent idea of the principle on which the majority of such machines are operated. This forms tiles six inches to twelve inches square, the die being placed

FIG. 206.



between the "push-up" and "plunger." It can also be used for making plates, oval dishes, and other ware.

In France great attention is at present paid to the manufacture of glazed or enameled tiles (tuiles vernissées ou encaustiques). The guiding points in glazing the tiles are either a white coating with the subsequent use of a colorless glaze, or a colored coating with a subsequent coat of a colored glaze. In the first case the white coating is simply a layer of white or

refractory clay, and the colorless glaze is either applied to the crude but perfectly dry product, which requires only one burning, or upon the biscuit, which requires two burnings. In the second case the preparation of the colored coatings is effected in the same manner as that of the colored masses, by mixing the coloring oxides previously triturated, melted and fritted together with an antiplastic substance, such as quartz, sand or feldspar, with white clay; the application is effected the same as colorless coatings.

If the glaze is laid upon a coating it will always present a brilliant and beautiful appesrance, free from cracks, while if directly applied to the mass it will always have a dull look. The latter method, to be sure, is cheaper, and favored by the action of a hot sun, is chiefly employed in Southern France, while the damp and dull northern part allows only of glazing upon biscuit.

As regards the glazes themselves they may either be free from lead or contain it.

Glazes free trom lead are prepared by fritting and subsequently grinding the following constituents:

Common salt, 40 parts; saltpeter, 22; potash, 22; powdered glass, 16. On account of its slight content of silica, this glaze is suitable for masses containing sand.

On the other hand, for a strongly clayey mass or one containing marl, the following mass, ground and fritted, is very suitable on account of its high content of silica:

Saltpeter, 20 parts; potash, 20; pulverized glass, 20; pulverized silex, 20; common salt, 10; clay, 10.

To those two formulæ, taken from Bronguiart, we add two methods according to Chaptal:

Dip the articles to be glazed in a dilution of Marviel-earth and, after drying, repeat the manipulation in water containing porphyrized glass. In burning the constituents fuse to an earthy alkaline colorless glaze.

According to the second method, dip the well-dried articles in a very strong solution of common salt, and burn. The silico-

alkaline glaze formed requires a mass containing silica for the formation of the silicate with the common salt.

In the following table we give glazes containing lead, the bases being lead monosulphide or galena (alquifour) and minium or red lead.

Color of the glaze.	Glaze containing lead.	Parts.	Minium glaze.	Parts.
Colorless	Galena	80	Minium	67
	White sand	12	White sand	24
	White clay	8	White clay	9
Yellow	Galena	78	Minium	63
	White sand	11	White sand	23
	White clay	8	White clay	9
	Minium	3	Sulphate of iron	5
Brown	Galena	78	Minium	60
	Sand	10	Freiland earth	33
	White clay	6	Sulphate of iron	5
	Minium	3	Manganese	2
	Oxide of manganese	3		
Black	Galena	77	Minium	58.6
	Sand	8	Freiland earth	32.3
	White clay	6	Sulphate of iron	4.6
	Ferric oxide	3	Manganese	2.3
	Oxide of manganese	3	Sulphate of copper	2.3
	Sulphate of copper	3	Black oxide of cobalt	0.04
Green	Galena	76	Minium	63
	White sand	12	White sand	23
	White clay	6	White clay	9
	Sulphate of copper	6	Sulphate of copper	5
Blue	Galena	81.0	Minium	66.5
	White sand	12.2	White sand	23.9
	White clay	6.5	White clay	9.3
	Black oxide of cobalt	0.3	Black oxide of cobalt	0.3

The cheaper galena, as compared with the more expensive minium, has the disadvantage of yielding, with the same weight, one-half less glaze, and hence is in the end as costly; on the

other hand, it is not nearly so dangerous as regards the poisoning of the workmen.

The manufacture of colored glaze tiles, as carried on in Munich and its vicinity, where it is very skillfully done, is much imitated in France. A brief sketch of the Munich process may, therefore, be of interest.

The mass prepared with great care consists of one volume of potter's clay, one-half volume of red clay, and one volume quartz sand, or one volume marl and one volume quartz sand, the following composition of glaze or enamel being especially suitable for this mixture. Great attention is also paid to the working of the glaze composition. The separate constituents are very finely ground dry and then treated with water. The composition consists of twelve parts by weight of lead-ashes, four of lithargyrum, three of quartz sand, four of white alumina, two of common salt, three of powdered glass and one of saltpetre.

Flat tiles having been carefully dried and strongly burned are, previous to glazing, placed for two days in water to free the surface from impurities acquired in burning and to slake the lime which may be contained in them.

For the purpose of glazing, the constituent parts of the glaze are sifted, thoroughly mixed and vitrified in glass pots. The glass thus obtained is finely ground, with the admission of water, in a mill, and in this state employed. By adding, prior to the preparation of the lead-ashes, twenty to twenty-five pounds of tin to every 100 pounds, the whiteness is considerably increased.

For the production of colored enamel to be applied with the brush, add to every 100 pounds of enamel mass the following substances, sifted and finely ground, whereby the respective colors are obtained. By greater or smaller deviations, all imaginary shades can be produced. For

Golden yellow	5.12 lbs. of antimony.
Pale blue	0.305 lbs. red ox. of cobalt
Violet	2.500 lbs. red manganese

Deep brown violet	5.000 lbs. red manganese.
Red	3.750 lbs. red manganese.
Green	2.500 lbs. copper ash.
Black	0.100 lbs. lithargyrum.
"	0.050 lbs. manganese.

In the manufacture of enameled tiles, lead-poisoning sometimes occurs. The great principles to be observed in all works where lead is used, are the inculcation of cleanliness; avoiding eating with unwashed hands, or in working-clothes, or in work-shops; moist grinding; free ventilation; precautions against dust raising, or wearing of flannel respirators when dust is unavoidable; and occasional doses of sulphate of magnesia acidulated with sulphuric acid. Sulphuric acid lemonade has been recommended as a drink.

In *acute* lead-poisoning from any cause, the stomach must be emptied by the stomach-pump, or by emetics—of which sulphate of zinc is to be preferred. Solutions of the alkaline or earthy sulphates—of which the best is sulphate of magnesia—are indicated, with the view of forming the comparatively insoluble sulphate of lead, and expelling it from the intestines.

Workmen who begin to show signs of lead-poisoning should at once give up the work, and take to some other employment.

THE MANUFACTURE OF CLAY-DUST TILES HAVING SURFACES IN RELIEF OR INTAGLIO.

Fig. 207 is a plan of a tile with an intaglio figure thereon, representing its use as a mould. Fig. 208 is a plan of a tile with a figure in relief thereon, also representing its use as a mould. Fig. 209 is a cross-section, illustrating the manner of their use. Mr. Low, the inventor of this process, uses a plastic material, like paraffine, and places it in the tile-frame of the tile-compressing machine, and subjects it to pressure, thus producing a flat thin plastic plate of about the thickness of a tile; or he takes a quantity of clay-dust and similarly compresses it, and saturates this dust with paraffine. The upwardly-presenting surface of this plate is then plentifully sprinkled

with pulverized plumbago, which is compressed into the surface of the plate.

The compressed plate may now be engraved with any desired pattern, care being taken to cover it with black-lead powder, brushed on with naphtha, or any other solvent of paraffine as a vehicle, or dusted on to a slightly-warmed surface, or stippled on with a stippling-brush. The parts denuded

FIG. 207.

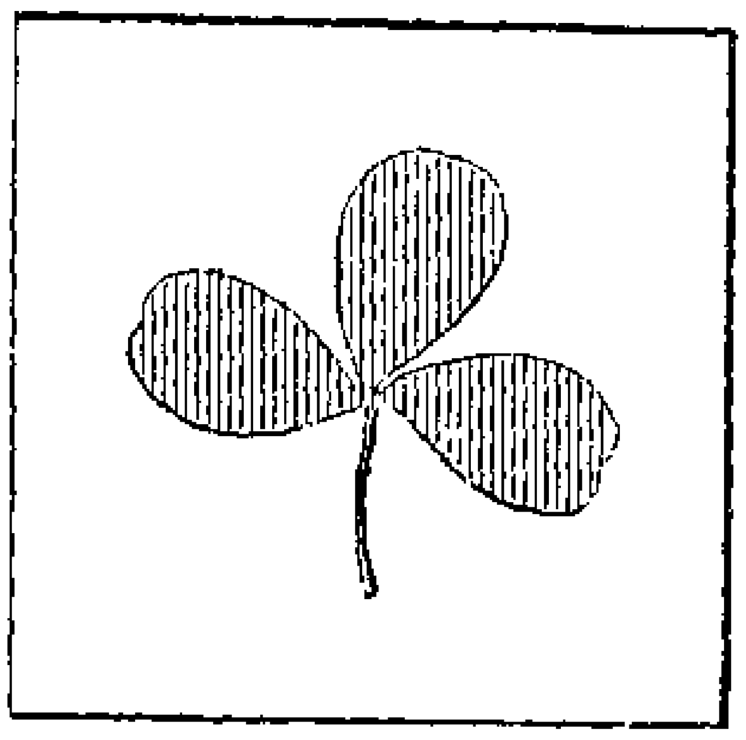


FIG. 208.

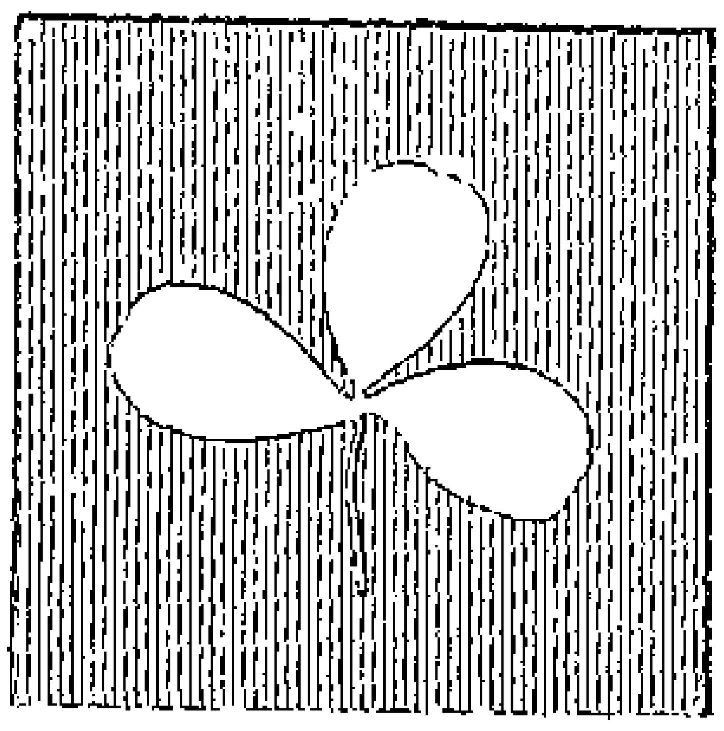
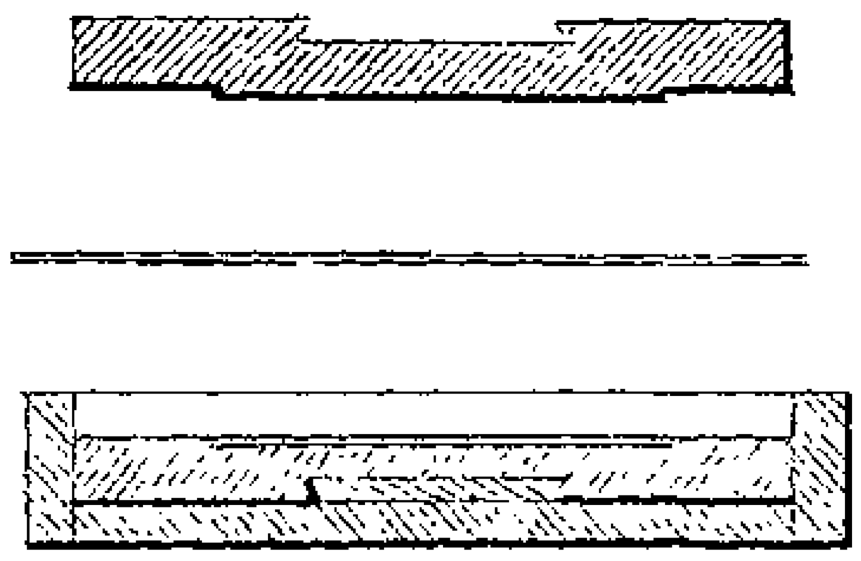


FIG. 209.



by engraving can be used as an electrotype mould to make a reverse, and the electrotype used as a matrix to make an obverse. These electrotypes, well backed, as when used for printing, and set in steel or other strong boxes to prevent crush of the backing, will serve as dies for making the intaglios and reliefs for stamping tile in dry-clay dust.

In case high reliefs are desired, the paraffine (or better, the clay and paraffine) plate may be carved, as desired, carefully avoiding under-cutting, and then covered with its plumbago surface, by the naphtha process or stippling, and electrotyped and used as the die.

When high reliefs, which it is desirable to undercut, are to be made, the mould is made so that the compressed clay will

draw, and the main part of the design being thus formed, the modeler carves the undercutting by hand, the clay being sufficiently tenacious when compressed to allow this, and the finished tile, partly hand-made and partly machine-made, is then fired.

For obtaining textures, low reliefs, or intaglios of natural objects, and the like, the inventor may, if he desires, use the paraffine plate made, as has been described above, with plumbago surface, for electrotyping; but, instead of engraving it, he forms an impression in its black-leaded surface by the objects he wishes to represent, in the manner hereafter described for unleaded paraffine or clay-dust. It is preferable, however, as it gives great variety in design with slight expense, to adopt the following manipulation: Having formed the compressed plate, as already described, raise in the tile-frame of the tile-machine the lower platen till the upper surface of the compressed plate is conveniently near the top of the frame, and compose upon the surface, by laying thereon bits of woven stuff, lace, pieces of embossed paper, leather, or other fabric, leaves, grasses, flowers, or other objects having suitable textures and outlines, such a design as will be attractive; then lower the platen to place, and bring down the plunger with strong compression upon the objects. By this means they are indented in outline and texture in the plastic or clay-dust surface, even overlays being represented with an accuracy absolutely true to nature, and always intaglio.

As already said, this intaglio may be used as a mould for electrotypes, when properly made, by the use of pulverized plumbago as a surfacing agent; but the inventor usually takes this matrix so made, and places over it a diaphragm of thin, tough material—a rubber film will serve, and many other materials; but the best and cheapest is the thin Japanese paper, of uniform texture and great toughness, such as appears in the Japanese handkerchiefs and napkins, so called. This diaphragm must exactly cover the surface of the intaglio. Upon it is next laid the dust of surface and body-clay of the tile to

be embossed, which is subjected to compression in the ordinary way, and thereupon, on raising the plunger and platen, the intaglio and relief may be separated, the diaphragm peeled by aid of a sharp tool to start it from the die, usually the relief, to which it generally, if not always, adheres, and the intaglio will usually, with proper care in handling, be found perfectly uninjured during several hundred impressions.

When the surface is of one clay and the body of another, each clay is to be separately compressed, unless *sgraffito* effects are desired, in which case the surface-layer must be carefully applied, so as not to cover the pattern desired to be of the color of the body-clay.

The sharpness and definition of texture of reliefs made from dust-clay intaglios are very remarkable, and tile compressed from dust from its homogeneous quality is much less likely to warp or shrink unevenly in firing than any other, particularly if packed in a less fusible powder, like quartz grains or canister in firing, as is not unusual with terra-cotta relief work. By these means is obtained what has long been a desideratum in relief tile-work—a compact homogeneous embossed tile of uniform quality and slight shrinkage—more surely than has ever been done before.

It may often be desirable to obtain in tile both the relief and intaglio of the impression in the clay-dust. In this case the relief can be used upon the platen in the same way as the intaglio. Two of these tiles, an intaglio and a relief, may be placed face to face in the sagger for firing, and usually will separate on removal; but it is best to insure this by leaving the paper diaphragm between them.

In case the design is to be reproduced smaller, the shrunk fired tile may be black-leaded and electrotyped.

Of course these tiles may have their intaglios filled with, or their reliefs covered with, kiln colors, slip, or enamel, either while simply clay or after firing, in any way and at any time proper in tile-making for such application.

No good method of fixing wall-tiles has yet been contrived.

except those used by the ancients of flanging or beveling the edges backward and forward on alternate sides or in alternating section on the same side, or in constructing them with holes partly parallel to their surfaces for cramps or wires extending into the plastic cement, all of which are costly, and none of which are adapted for compressed clay-dust work.

Lately on occasions, in wet-clay work, undercut cramp-grooves have been made by hand; but these are costly and inapplicable to dust-work.

Mr. Low employs the following means for forming dovetailed grooves on the backs of tile: He cuts one or more pieces of wood of dovetailed cross-section to such length as may be desirable, usually long enough to extend clear across one way, and lays them on the platen of the tile-machine narrow side down, and fills in the clay-dust upon them, or he places them on top of the filled-in dust, narrow side up, according as the face of the tile is to be up or down. In compression the narrow face of the wood will be level with the back of the tile, and the clay-dust will mould round it. In firing, these formers will burn out, leaving their grooves, and this, if the wood be soft, light, and dry, without much, if any, chance of injury to the tile.

Many things may be used as substitutes for paraffines, such as waxes, and compounds of waxes, resins, gums, etc.; but we have not considered it requisite to enumerate them, as they would clearly be equivalents if their qualities of toughness, flexibility, and plasticity resembled those of paraffine.

The clay-dust used should be fine enough to pass a one-hundred-mesh sieve at largest.

THE MANUFACTURE OF WET-CLAY FLOORING TILES.

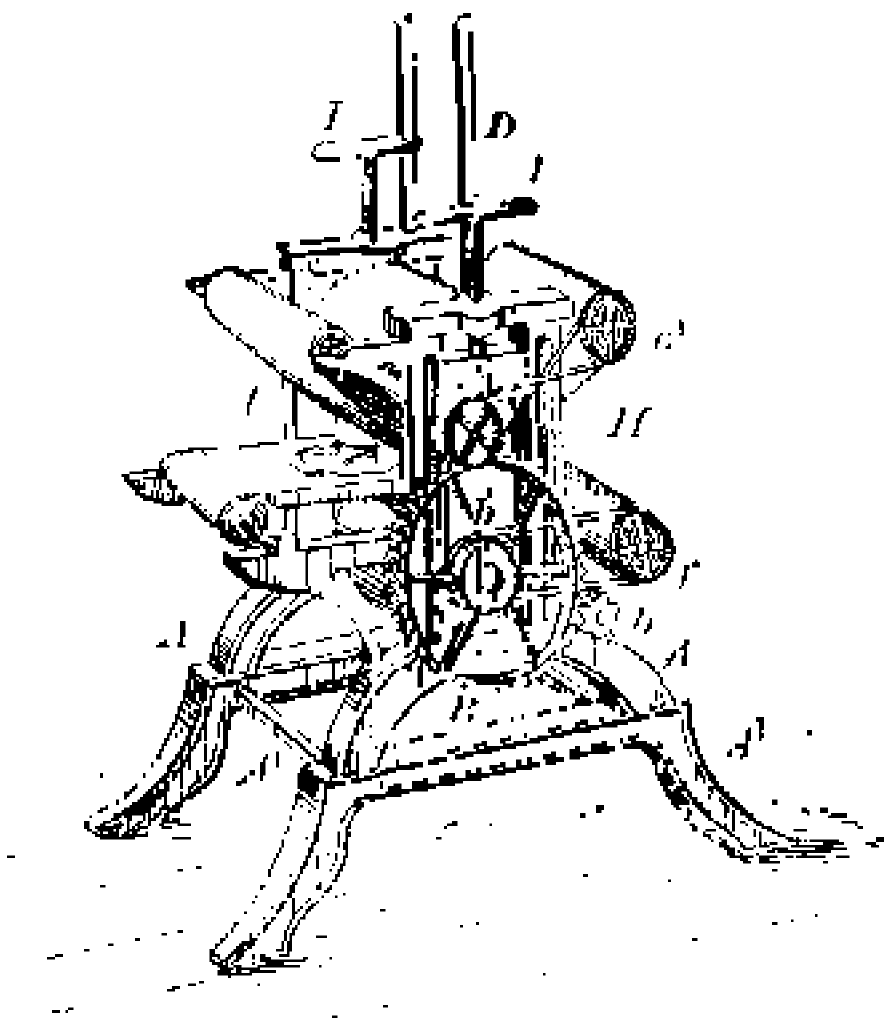
The machine shown in Figs. 210 to 219 is the invention of Mr. George Elberg, of Columbus, O., and is for the manufacture of flooring tiles in connnection with his process.

He first prepares a thin sheet of clay on paper, which forms the finished surface of the tile-blocks. The second step consists in the method of cutting up the clay sheets into suitable

sizes to make the finished face of the tile; and the third step consists in the method of combining the clay sheets with a suitable body of clay to be pressed and burned to make the finished tile-blocks.

Fig. 210 is a perspective view of a machine for making the

FIG. 210.



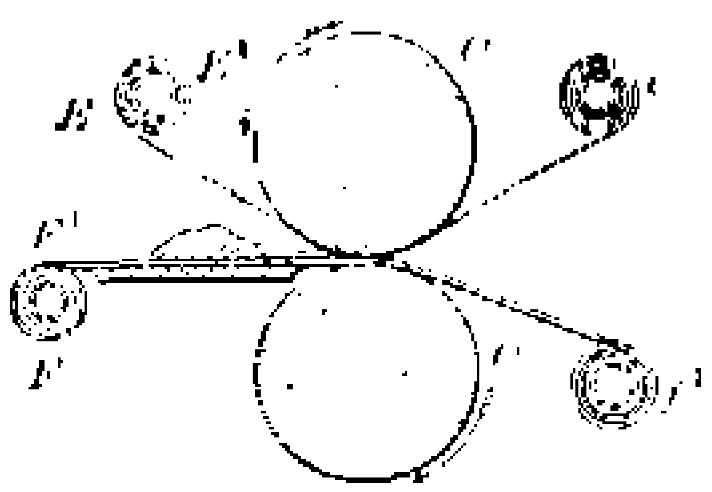


FIG. 211.

veneered tile surface. Fig. 211 is a central cross-section, showing the relative relation of the rollers shown in Fig. 210; Fig. 212, a side elevation of a machine designed for the second step of the process; Fig. 213, a front elevation of the same. Fig. 214 is an enlarged side elevation of the roller-adjusting mechanism, shown in Fig. 212; Fig. 215, a broken section on line *x x* of Fig. 214; Fig. 216, a perspective view, showing detached parts of the treadle mechanism; Fig. 217, a plan view of the cutting-dies; Fig. 218, a longitudinal section of the cutting-dies and follower-board; and Fig. 219, an elevation of the rack and pinion.

A represents the body or frame of the first machine; *A*¹, the legs on which the parts are supported. The frame of the ma-

FIG. 212.

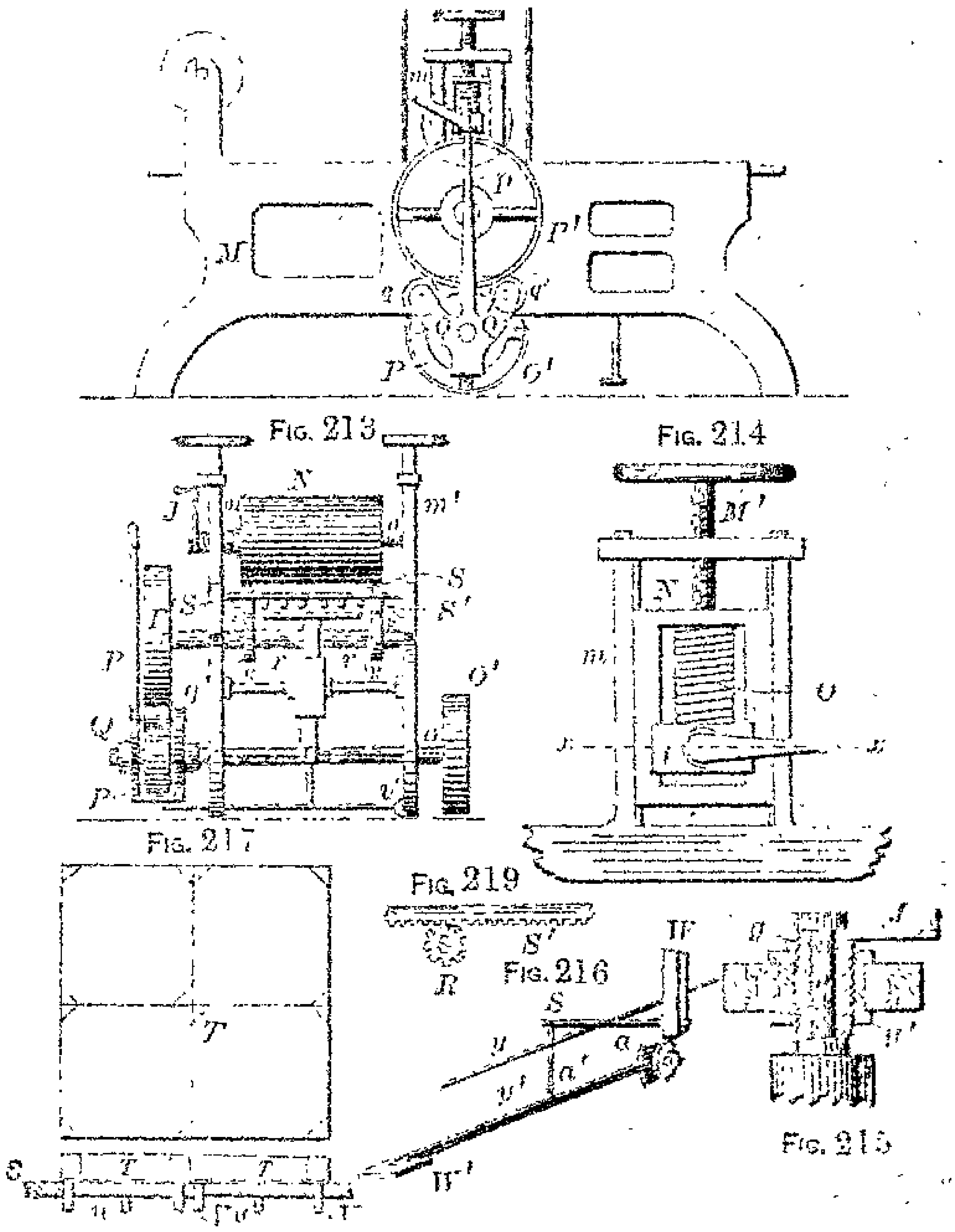


FIG. 218.

chine may be made of any suitable material, and should be substantially built.

b represents a pinion mounted on a shaft supported in journals on frame *A*, which is driven by a belt *D*, running over a pulley on the end of a shaft opposite to pinion *b*. Pinion *b* drives the large gear-wheel *B*, mounted upon the axial shaft of roller *c*.

h represents a pulley on the same shaft.

f represents a transmitting-pulley, mounted on axial shaft of roller *F*. This axial shaft of roller *F* is journaled upon the frame of the machine in any suitable manner.

H represents another transmitting-pulley, journaled to the frame of the machine on an independent shaft. Upon the outer end of the shaft is a transmitting-pinion, not shown in drawings, and meshing with gear *B*.

c' represents a pulley mounted on the axial shaft of roller *c*, driven by a belt from pulley *H*, as shown in Fig. 210.

The paper may be burned off in the kiln, or removed after the tile has been completed and thoroughly dried ready for burning, leaving an excellent finished surface.

When delicate colors are to be used, it is preferable to remove the paper before burning; but in some cases the paper will burn off in the kiln without injury to the color.

The thin sheets of clay formed on paper we believe to be a new article of manufacture. The sheets of clay so prepared are united with an additional body of clay. The preferred process of carrying out this part of the invention is described as the third step.

The object of the machine shown in Figs. 220 to 228 is to press the tile on carrier-plates, which are first oiled; then the clay or tile blank is placed upon the carrier-plates, passed under an oil-roller, thence carried between dies and into a die box, where it is subjected to pressure to shape and form the tile, then delivered out of the dies by the automatic and intermittent action of the machine driven by power, the motion of the machine being imparted by means of an oscillating shaft, from which shaft all parts of the machine primarily take their motion to successively carry out the various steps of the operation.

Fig. 220 is a side elevation of machine for oiling the carrier-plates; Fig. 221, an end elevation of the same. Fig. 222 represents the carrier-plate. Fig. 223 is a perspective view of the pressing-machine; Fig. 224, an end elevation of the same; Fig. 225, a plan view of the reversing-gear; Fig. 226, a longitudinal section on line *x x*, Fig. 224; Fig. 227, a detailed view of one of the outside eccentrics operating the die-arms; Fig. 228, a detailed view of die-arm with die removed.

A, A', A^2 represent the frame of apparatus; a', an endless car-

rier traveling over pulleys *a a*; a^2, carrier-blocks secured to belt a^1; *B b*, a ratchet and pawl; B^1, a belt connecting pulley *b*, to driving pulley B^2, rigidly secured to shaft *S*.

FIG. 221.

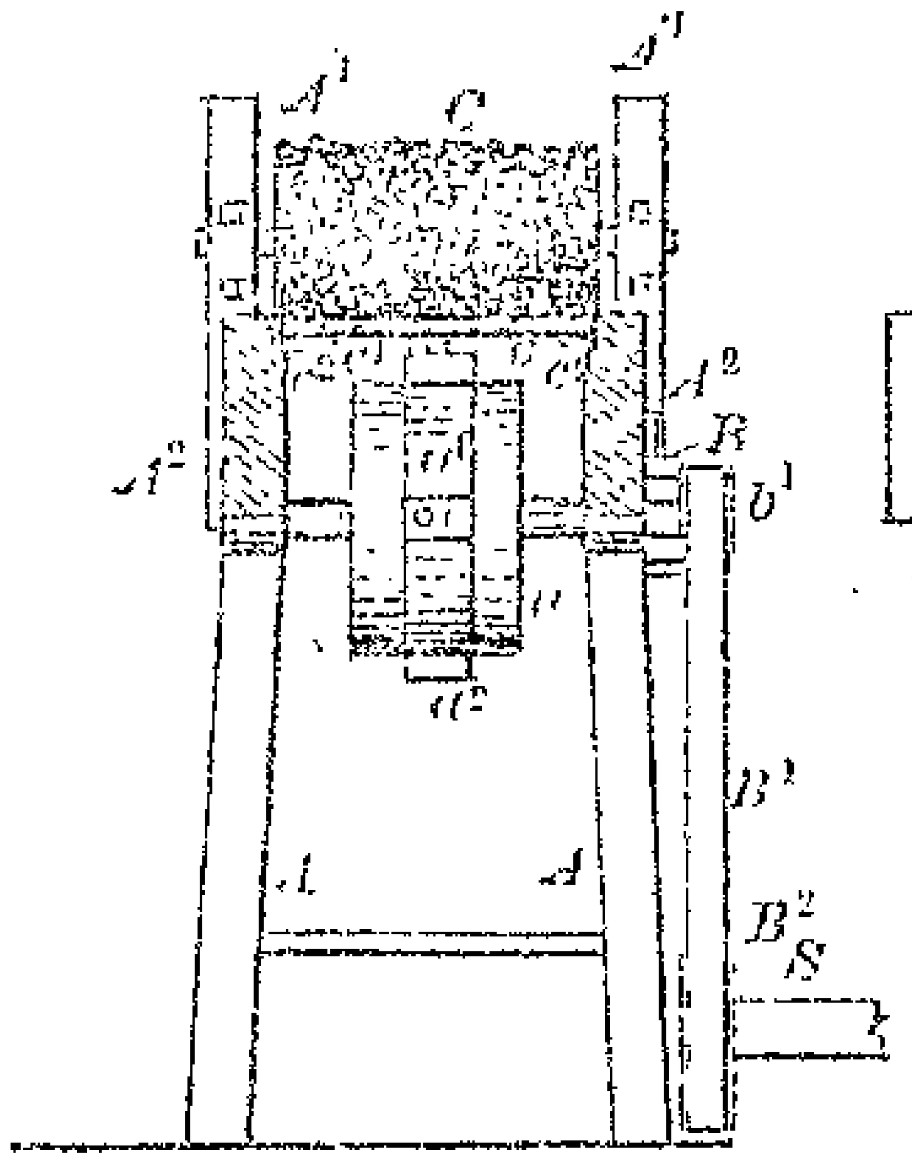
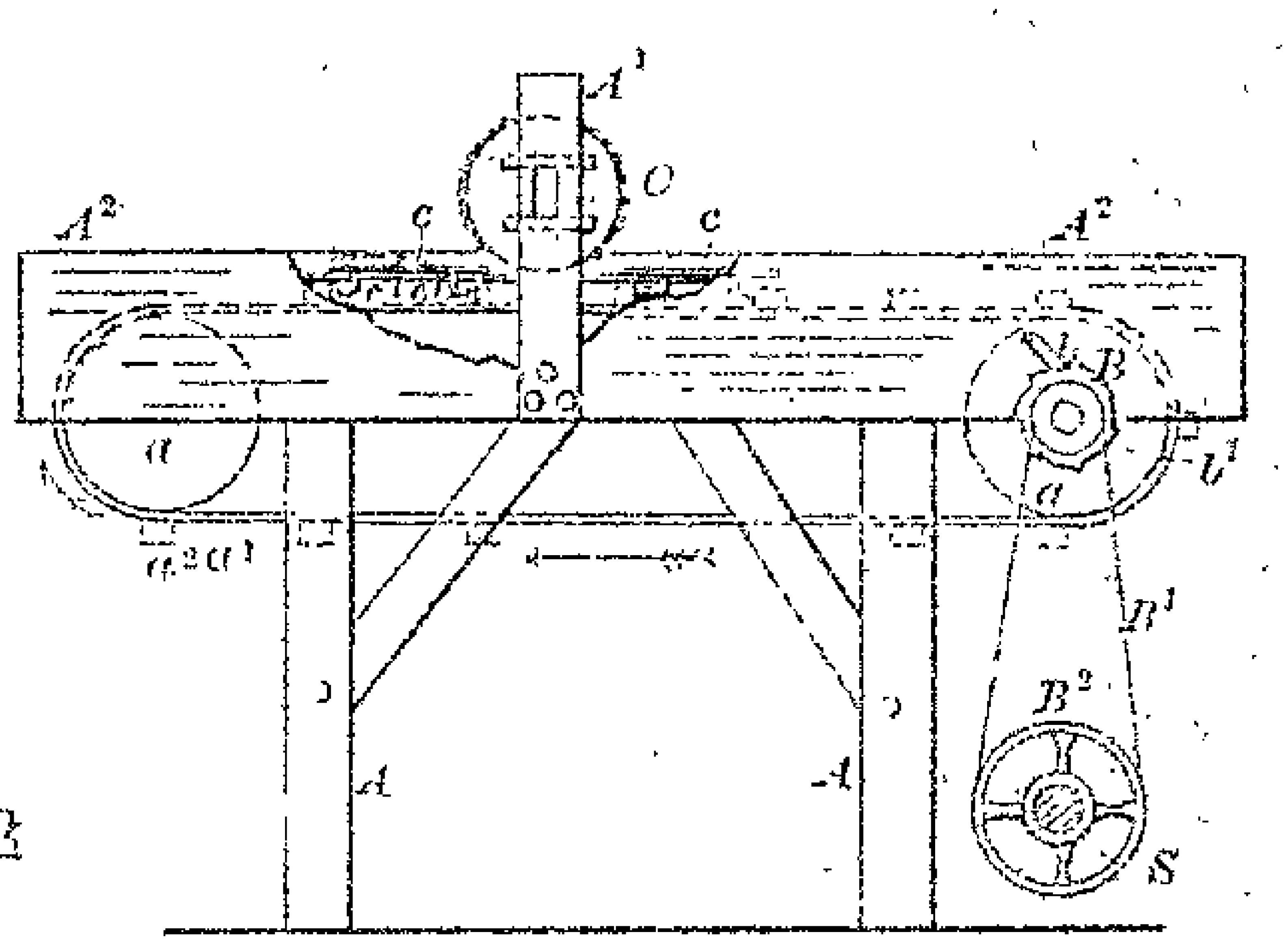


FIG. 220.



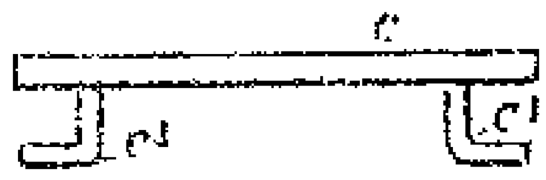
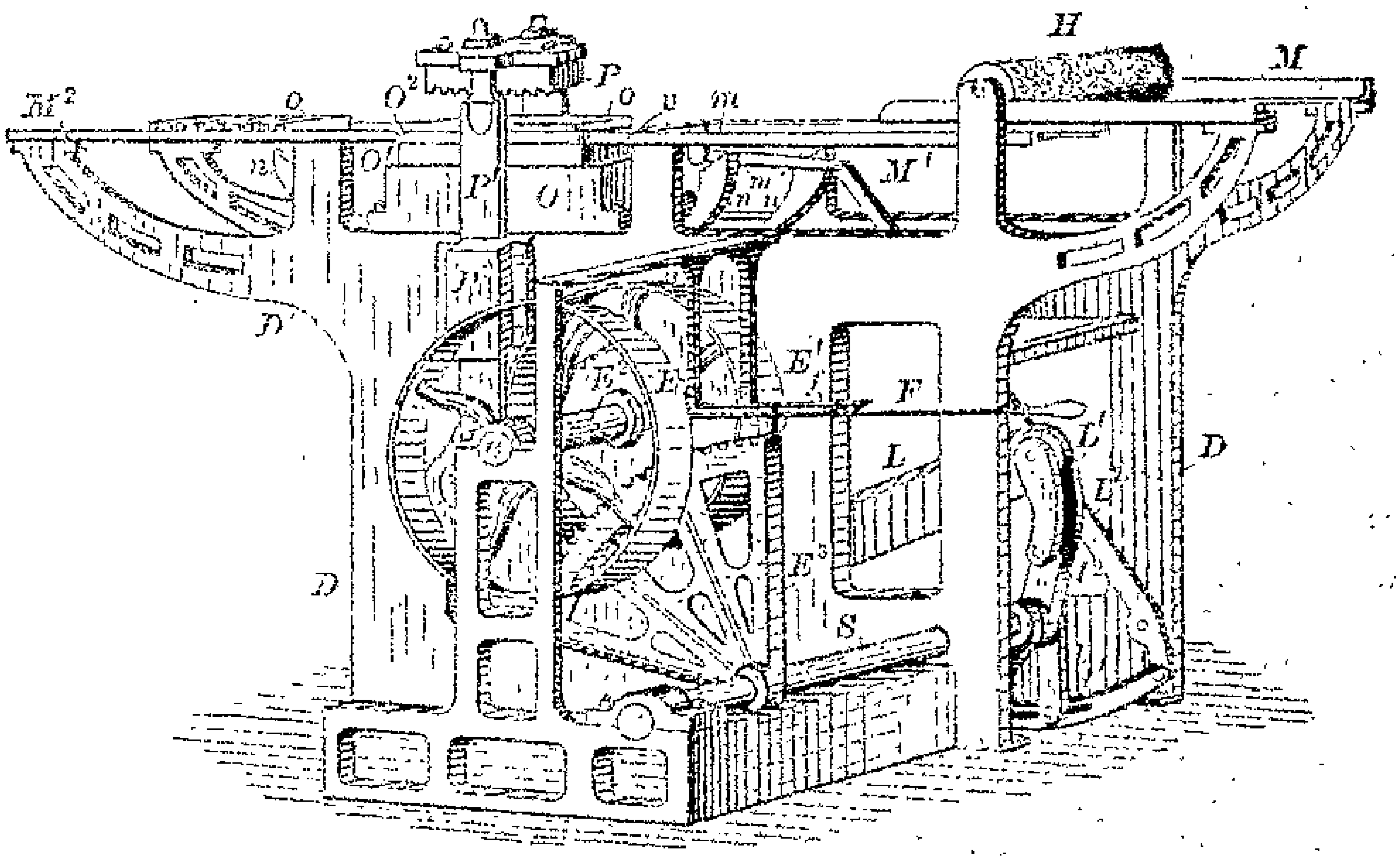


FIG. 222.

FIG. 223.



C is a roller covered with sheep's pelt or other porous substance designed to hold oil; *c*, the traveling plates, on which is placed the clay. c^1 are depending legs or hooks engaging with the carrier-blocks a^2; c^2, angle-irons, which act as ways for

plates c. The plates c are placed upon the angle-irons or ways c^2, then, by means of the carrier-blocks a^2, are carried under

FIG. 224.

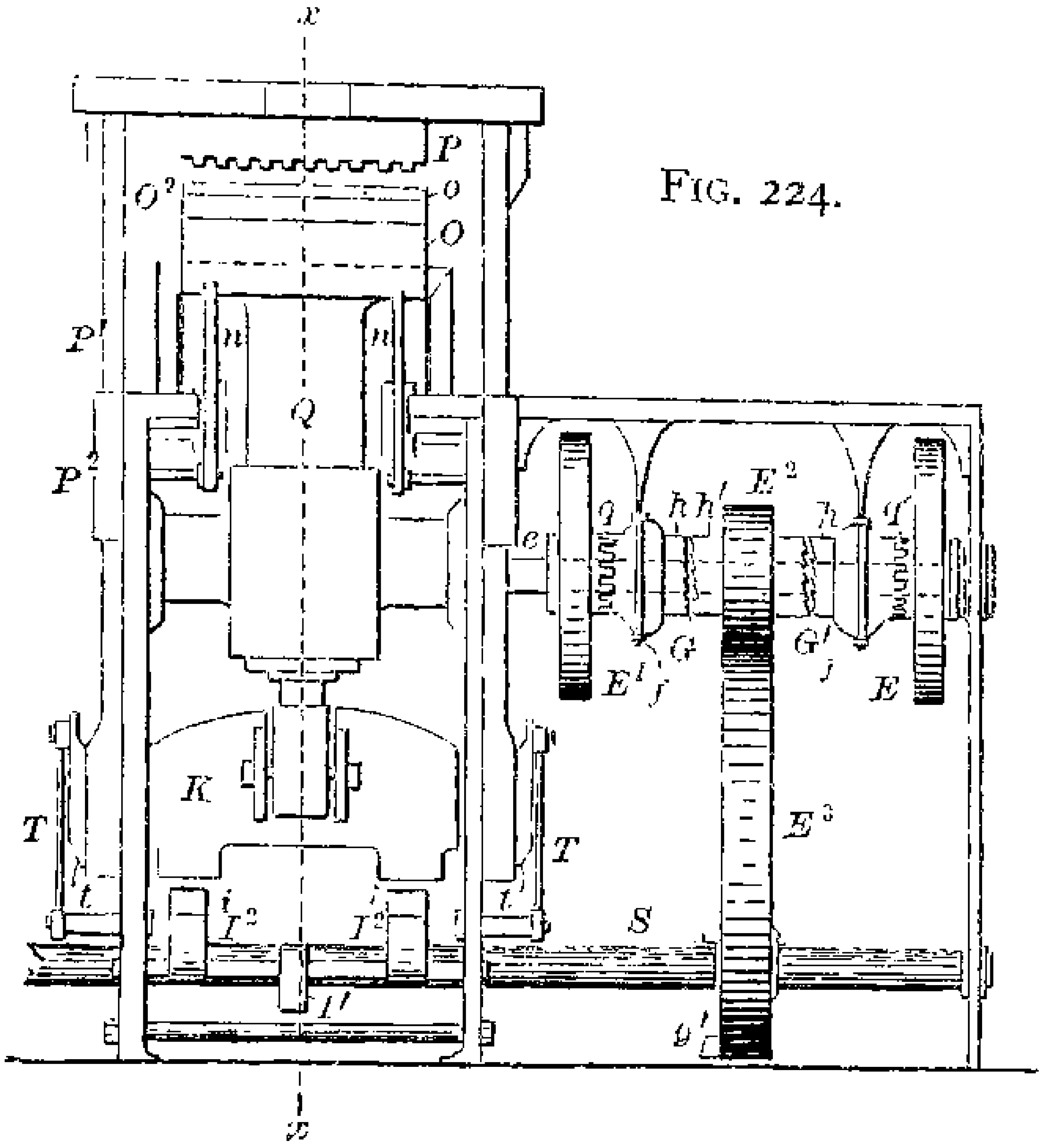


FIG. 225.

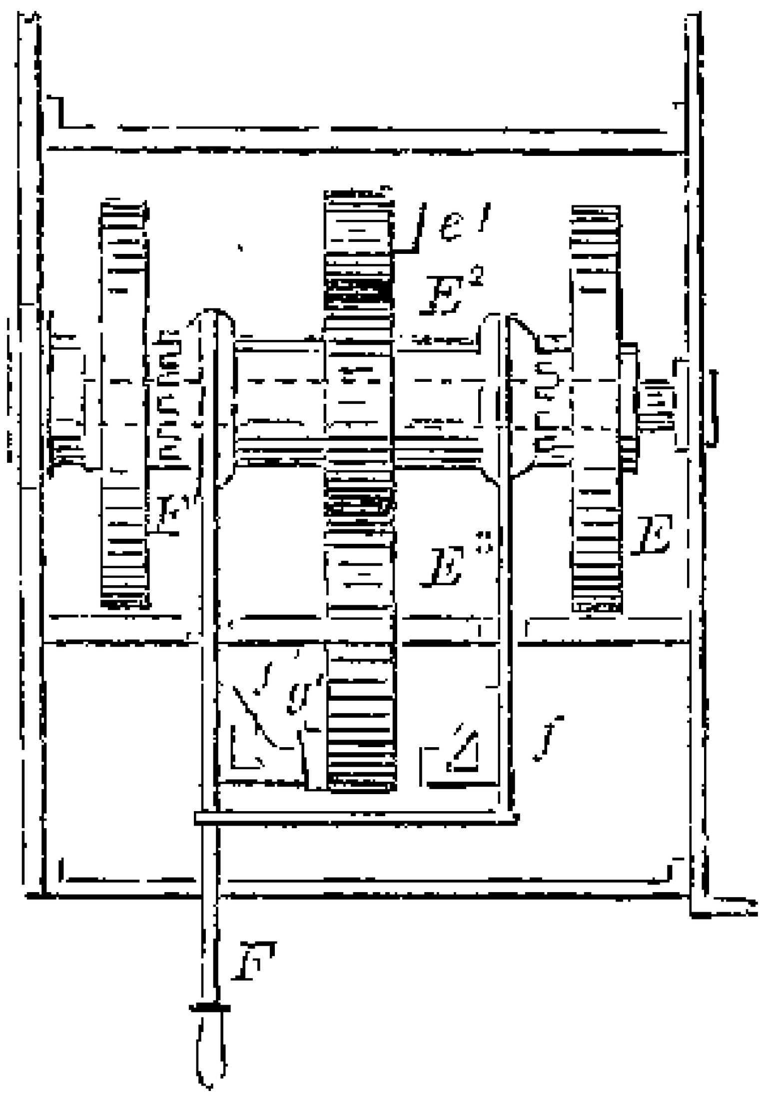
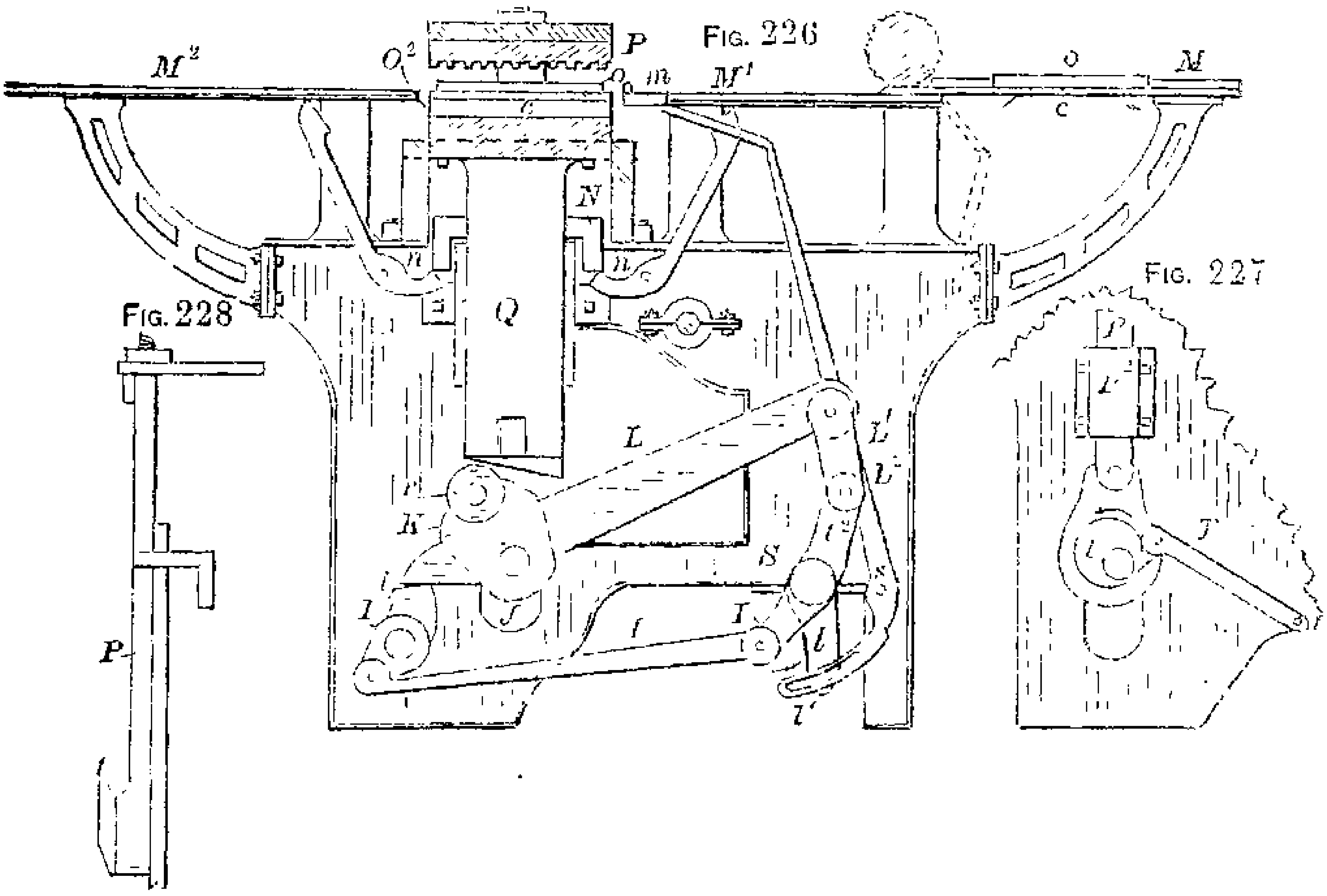


FIG. 226 FIG. 227 FIG. 228



roller C, which oils the surface. When they reach the other end of the machine they are taken off by the operator and blanks of clay placed upon them.

CHAPTER XVI.

THE MANUFACTURE OF ROOFING-TILES; THE GLAZING OF ROOFING-TILES.

GENERAL REMARKS.

THE word tile does not often occur in the Bible; but that tiles were used in very ancient times, not only in buildings, but also for many purposes for which we employ paper, there is not the least doubt, and this is particularly true in regard to Assyria, in which country almost every transaction of a public or private character was first written upon thin tablets of clay, or tiles, and then baked.

The prophet Ezekiel, who was among the captives near the river Chebar in the land of the Chaldeans, is among the first to describe the use to which the tile was sometimes put for receiving drawings or portraying of plans.

In 595 B. C. Ezekiel was commanded to make use of this Assyrian practice at the time when the siege of Jerusalem was prefigured, the commandment being in the following language: "Thou also, son of man, take thee a tile, and lay it before thee, and portray upon it the city, even Jerusalem." Ezekiel iv. 1.

The plan of the siege and all the details were fully explained, and the manner and period in which they were to be carried out were predicted.

From the profuseness with which the Assyrians employed colors in the decoration of bricks and many interior as well as exterior architectural positions, and in their most gorgeously dyed apparel and head-dresses, household furnishings, horse equipments, and in fact every position that it was possible to attract the eye or please the taste, it is not improbable that when tiles were used for roofing purposes they were also richly

colored and ornamented in a great variety of designs, imparting to the roofs a highly ornate appearance.

Rome was originally roofed with shingles, which gave a general invitation to the great destructive fires which so often occurred; and no effort seems to have been made to lessen the danger from this source until about the time of the war with Pyrrhus, at about which time tiles of burnt clay were introduced.

In Knight's "Mechanical Dictionary" we find three good illustrations, with description of the tiles used by the Greeks and Romans, and modifications of the pantile. About the time of Pausanias, 620 B. C., tiles of marble were largely employed in Greece; the temple of Jupiter at Olympus, and of Athenæ at Athens (the Parthenon), were thus covered.

The ancient Greeks always clung to marble; at no time did they show any great desire to employ burned clay in their architectural constructions. Roof-tiles of bronze and gilt were used in some cases.

The lower edges of the joint tiles were protected and ornamented by *frontons*, and the edges of the flat tiles were turned up and covered by semi-cylindrical joint tiles, termed *imbrices*.

FIG. 229.

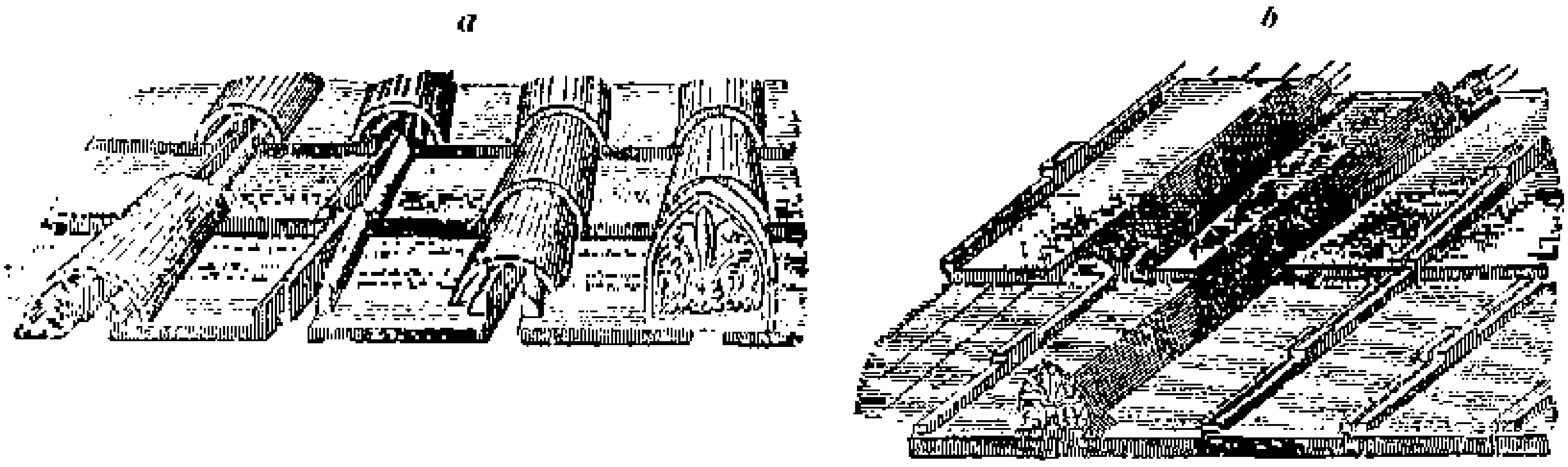


Fig. 229 shows two forms of marble tiles, *a* being the form employed by the Romans, and *b* the marble tiles sometimes used by the Greeks; and which have both been imitated in clay.

In Roman architecture, both flat and round tiles were largely employed, roofs were not uncommonly covered with flat and curved tiles alternating.

The plain tiles now in general use in England weigh about from two to two and one-half pounds each, and expose about one-half their surface to the weather, four hundred of them covering one hundred superficial feet of roof surface; they are sometimes hung upon the sheathing-board by two oak pins inserted through holes left by the moulder.

Plain tiles are also now made with grooves and fillets on the edges, so that they can be laid without overlapping the usual distance, the grooves leading the water. This may answer for some cheap constructions where lightness is also a consideration; but the plan is a bad one, as they will certainly leak in the driving rains and drifting snows, and they are also subject to injury by hard frost.

Pantiles were first used in Flanders, the wavy surface lapping under, and being overlapped by the adjacent tiles. The English pantiles weigh from five to five and one-quarter pounds, expose ten inches to the surface, and one hundred and seventy-five of them cover a square, or one hundred superficial feet of roof surface.

A gutter tile has come into use in England; it forms the lower course, overhangs the lower sheathing-board or lath, and is nailed to it.

Sliding tiles are used as substitutes for weather-boarding; holes are made in them during moulding, and they are secured by flat-headed nails to the lath.

The exposed face, called the gauge, is sometimes indented to represent courses of brick; fine lime mortar is introduced between them, when they rest one upon the other.

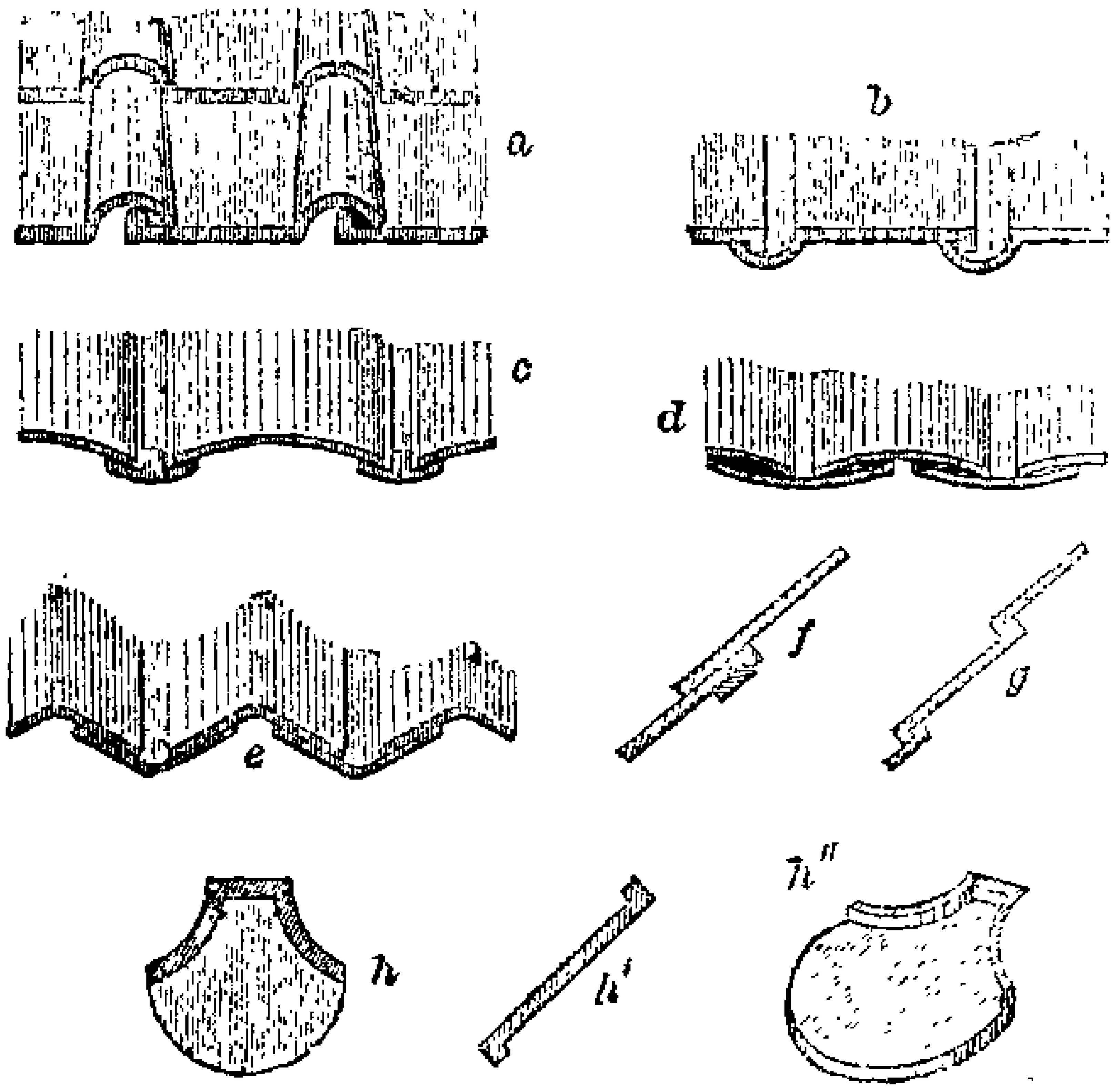
These sliding tiles are sometimes called weather-tiles, and sometimes mathematical-tiles, the names being derived from their exposure or marking. They have a variety of forms, having curved or crenated edges, and are also variously ornamented with raised or encaustic figures.

Modifications of the pantiles are shown in the examples *a b*, Fig. 230, the edges being turned up and down respectively; *c d e* are modifications of the ridge-tiles, in which the gutter

and ridge are placed alternately. *f g* show modes of securing; the first is moulded with a lug, which secures itself in position by catching above the lath of the roof; the second shows a tile moulded with two lugs, by which it engages the tiles of the courses above and below.

h, *h'*, *h''* are elevation, section, and perspective views of a tile exposing a semicircular face to the weather. The semicircular portion has a drop flange, which catches over re-entering curves of the upper part, these curves having upturned flanges for that purpose. Whenever roof-tiles are to be glazed, they are varnished after being burned; the glaze is then put on, and the

FIG. 230.



tiles are then placed in a potter's oven and remain until the glaze commences to run. The glaze is usually made from what are called lead ashes, being lead melted and stirred with a ladle till it is reduced to ashes or dross, which is then sifted, and the refuse ground on a stone and re-sifted. This is mixed with pounded calcined flints.

A glaze of manganese is also sometimes employed, which gives a smoke-brown color.

For a black color iron filings are sometimes used; for green,

copper slag; and for blue, smalt is employed, the tile first wetted, and the composition laid on from a sieve.

At one time very inferior roof-riles were made in England on account of the careless weathering or preparation of the clay employed; and in order to cure this a statute of Edward IV. required that all clay for tiles should be dug, or cast up, before the first of November, and not made into tiles before the March following.

The garden of the Louvre in Paris was called the Tuileries, as being a place where tiles were anciently made; a magnificent palace was begun there in 1564 by Catharine de Medicis, wife of Henry II., finished by Henry IV., and splendidly adorned by Louis XIV., but was sadly defaced in our times, during the Commune of 1871.

Modern tile-covered roofs add greatly to the picturesque appearance of buildings.

A portion of a roof covered with diamond shaped tiles is shown in Fig. 231, and the form of the tile is shown in a section, and a plan of face and bed.

Fig. 232 shows a roof covered with tiles of various shapes, and Fig. 233 shows the six forms of roofing tiles in most common use in this country.

A great advantage for the tile roof is that it is a non-conductor, and, therefore, cooler in the summer season than any other kind of roof. The buff tile, being lighter in color, is the coolest, as it does not absorb the rays of the sun. Tiles are also a better protection against lightning than the lightning-rod, as the latter attracts electricity, while the former is a non-conductor. Insulators, made of pottery, are extensively used on telegraph lines in Europe and portions of America.

The rain-water collected from a tile roof is much purer and cleaner than from any other kind of roof, as the tiles are very smooth, and no dust or soot settles upon them.

Tiles are indestructible, and are not affected by heat or cold. They will not crack and slide off the roof, like slate, leaving the sheathing exposed, when subjected to sudden heat, as by the burning of an adjoining building.

FIG. 231.

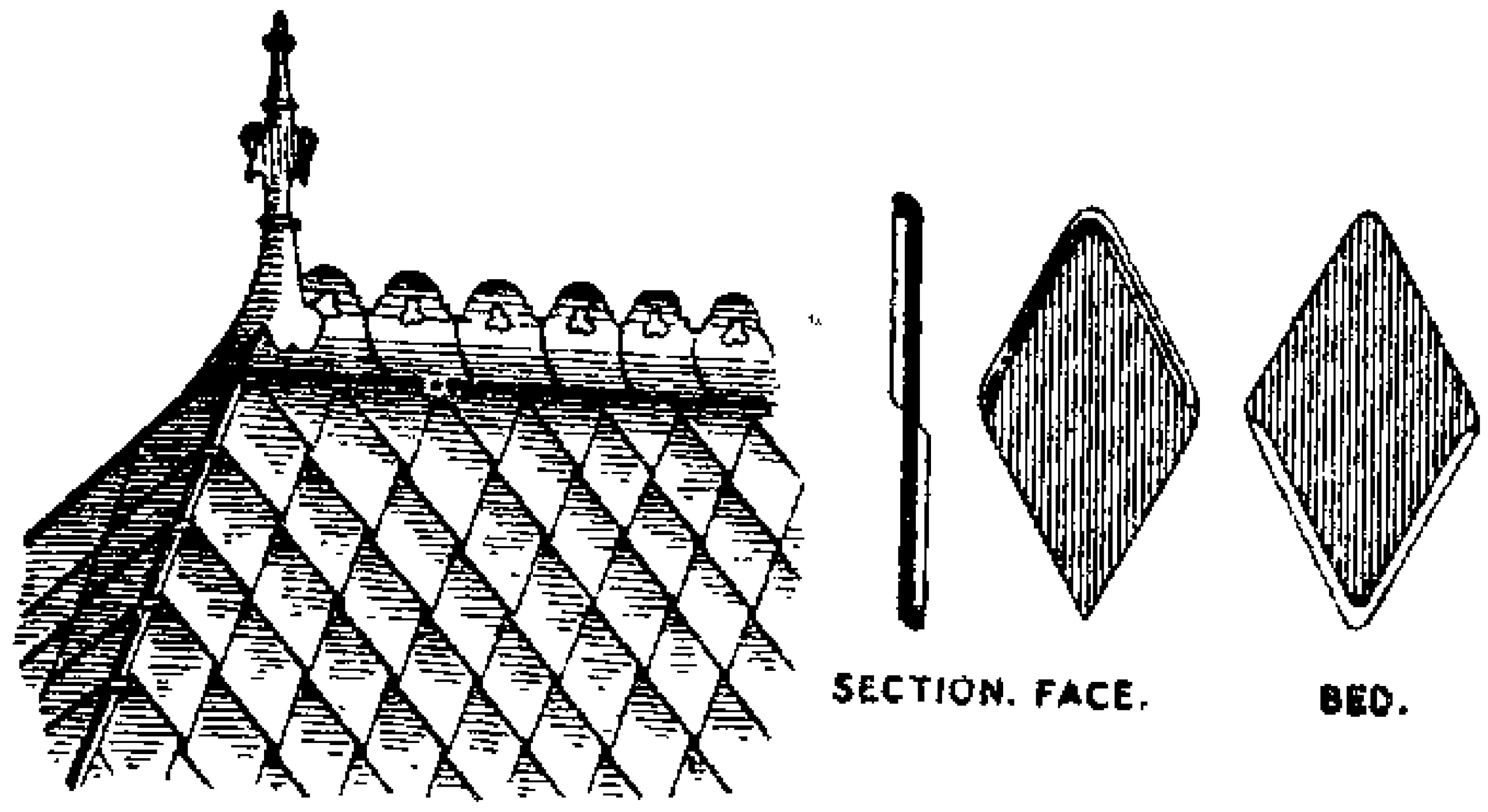


FIG. 233.

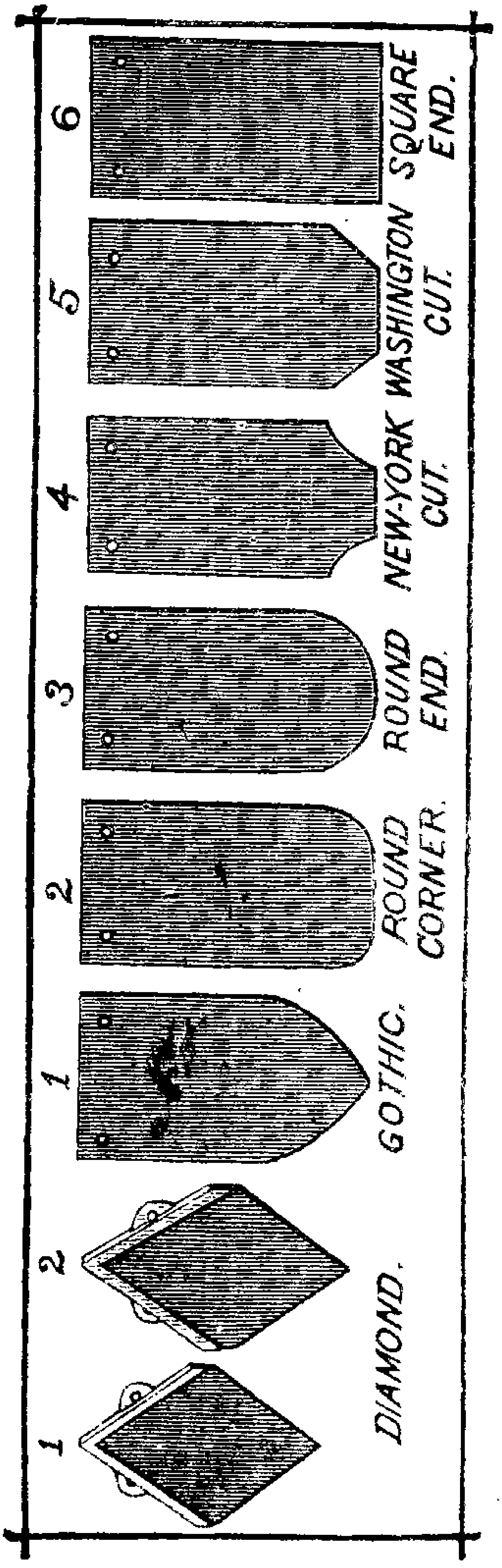
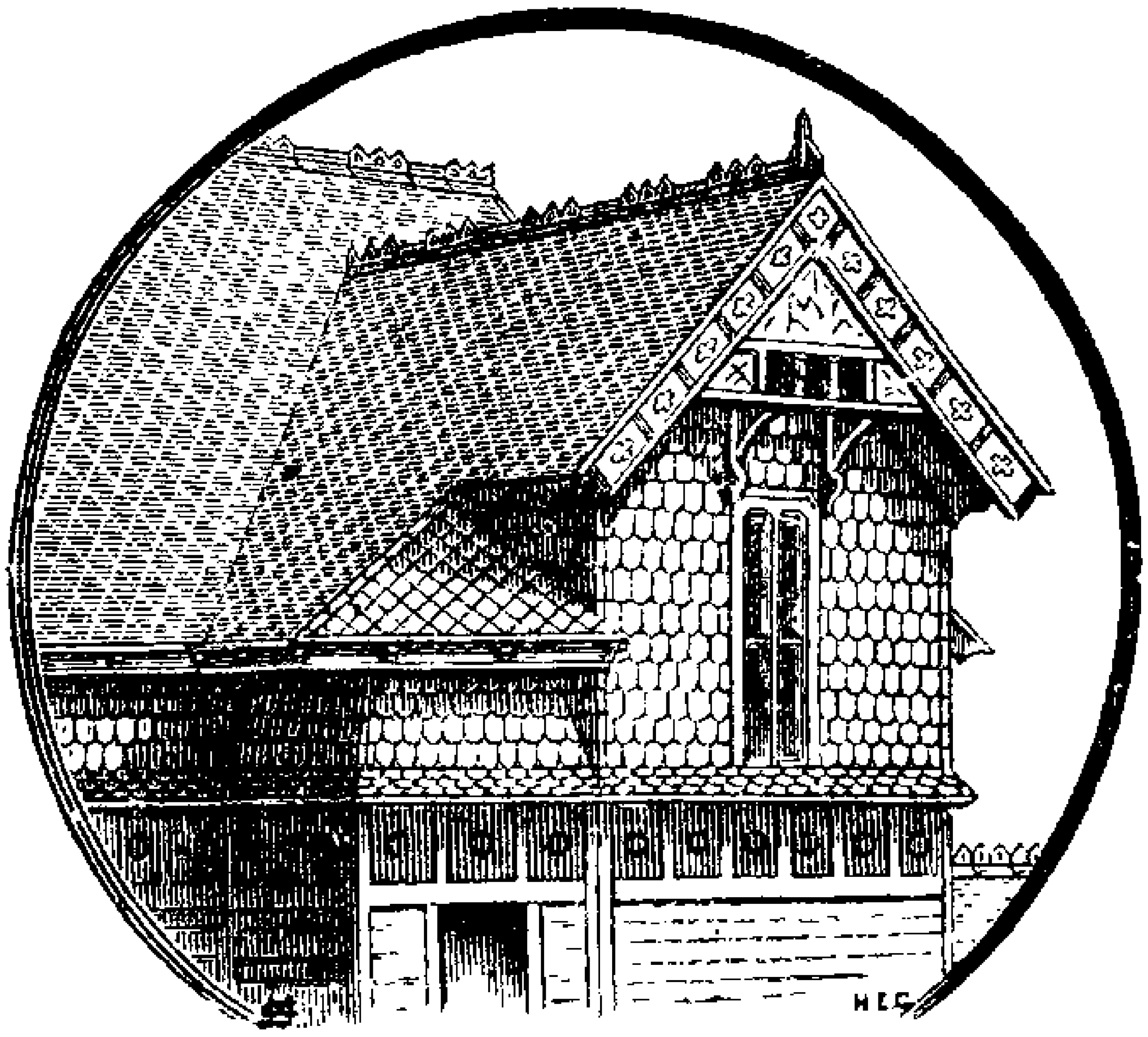


FIG. 232.



After doing service on one structure, the tile can be taken off and used on other buildings. Tiles should not be put upon a roof that has less than one-quarter pitch (a slant of six in

to the foot), although we have seen some roofs of less pitch which were satisfactory. A roof to support tile should be somewhat stronger than for shingles. The rafters should be 2x6, 18 inches apart, and well-stayed, so that they cannot spread. The sheathing should be of soft wood, of even thickness, and close together. Generally felt or tarred paper is placed under the tile, although it is not necessary to make the roof water-tight, but it stops circulation, and makes the roof warmer in winter, and adds but little to the cost.

THE PROCESS OF MANUFACTURING ROOFING-TILES.

When the process of manufacturing roofing-tiles is conducted by hand, the method is nearly the same in this country as in England, and but few improvements have been made in this mode of production; but by the machine process we are enabled to manufacture very satisfactory roofing-tiles at but a small cost.

The clay of which the tiles are made is dug and spread out in shallow beds to disintegrate, and a hot sun or dry frosty weather is best for this.

In all cases the clay should next be finely pulverized by passing through iron rollers or other suitable appliances, and too much care cannot be given to this branch of the preparation of the clay, as has before been observed.

A good pug-mill is one which can have the knives made larger at the top than at the bottom and used for tempering the clay when the tiles are made by hand.

The usual form of pug-mill employed in England is generally six feet high, three feet in diameter at the larger or upper part, and two feet at the bottom.

The clay is kneaded and completely mixed by a revolving cast-iron spindle, which carries a series of flat steel arms, so arranged as to form by rotation a worm-like motion upon the clay, which is pressed from the larger to the smaller diameter of the tub in which the clay is confined, and finally comes oozing out of an aperture in the bottom. In this manner of tempering great cohesive power is given to the clay.

The clay is then ready to make roofing-tiles; the moulding is usually conducted in a shed, and most of the manufacturers prefer to place their tiles in the open air, if the weather allows.

The moulding table or bench is supported on four legs, which are well under the table, leaving the two ends of the top of the table to project liberally. The coal-dust box, 14x8 inches, is at the left hand of the moulder, at the corner of the table, and the moulding-board, 14x10 inches, is usually placed slightly to the right of the coal-dust box.

The mould employed is 12x7¾ inches and ½ inch thick, made of oak, and usually plated with iron.

The moulder works a lump of clay by hand into an oblong square, the mould is placed on the bench, and fine coal-dust sprinkled over it; the lump of clay is then taken up and thrown into it with force, which is cut off level with the top of the mould by a brass wire, strained upon a wooden bow; the lump of surplus clay is removed, and that in the mould is finished by adding a little clay to it, if necessary, and smoothing the face over with a wooden tool.

The moulded tile is then placed upon a thin board, first sprinkled with fine coal-dust, and so the process is repeated, the lump of clay being added to every time six tiles that are moulded. The off-bearer carries two tiles at a time, one on his head and one on his hands, to the floor, where they are allowed to remain for four hours out of doors in fair weather, and then collected and placed together, the nib end changed alternately, so as to hack them closely and squarely.

In this condition they remain for two days, so as to allow them to toughen; the situation of this hacking should be dry, but not hot.

The set or curved form is then given by placing six of the tiles at one time on the top of the horse, which is a three-legged stool, having the top about three-quarters of an inch longer than the tile, the top being a convex curve to a radius of about 10 feet and 3 inches, and having a height of about 2 feet 7 inches from the level of the ground to the top of the block.

The nib end is reversed each time so as to allow the tiles to lie closely together without injury, and a wooden block lifted on top of the tiles, raised by the projecting ends, and three quick blows given with it on the tiles; this block is concave and curved, so as to correspond with and fit neatly over the upper surface of the horse.

The tiles are then carried away and stacked edge together in the shape of a half diamond, three tiles being used to form each side; two laths are then placed on the top of the first hack of tiles, one lath at each outer edge; another hack of tiles is placed on the laths, so arranged as to form a full diamond with the openings left between the first course of tiles; two laths are then placed in the same way on the top of the second course of tiles, and the third course is then hacked so as to form a full diamond, with the openings left between the second course of tiles.

This is the final drying, and they are then carried to the oven twelve at a time, with the edges of the tiles resting against the breast of the carrier.

Objections to roofing tile, in this country, have heretofore been made to the effect that the tile was heavy, made of coarse clay, poorly burned, that it would absorb a great amount of moisture, so that freezing and thawing would cause it to crumble, and. in appearance, it was anything but handsome. Whatever foundation these objections may have had in the first product of tiles, our manufacturers have now fully met and remedied these drawbacks to their use.

All roof-tiles require more careful burning than brick, and before they are placed in the oven, the bottom is covered with brick, so as to take the first flash of the fire, which would destroy a course of tiles in that position from the warping and discoloring.

On the top of this course of brick about nine thousand tiles are set, which form a square in the heart of the kiln, the space between the tiles and the curved sides of the oven being usually filled with brick.

The tiles are set edgewise in lots of twelve, called bungs, changing their direction with each lot, being set cross and lengthwise alternately. They are placed in a vertical position, and the nibs of the tiles space them off from each other and support them in a vertical position; the checkered manner in which they are placed in the oven insuring full action of the fire through the stock.

A uniformity of heat is a great desideratum in burning tiles, and the old form of circular oven, so much employed in Staffordshire, is found to answer the purpose, and do the work more thoroughly than any other in use.

A wall is sometimes built around the oven in order to protect the fires, and prevent one from being urged more than another by the changing direction of the wind.

A sufficient space is left between the wall and the oven to allow the fireman to attend conveniently to his fires; five feet six inches usually being high enough for this wall.

The oven having been filled, the doorway is walled up with brick and faithfully daubed over with loam and sand, the fires are lighted and kept slowly burning for the first five hours, after which time they are then progressively increased for the next thirty-three hours, making the total time thirty-eight hours for hard-fired tiles, four tons of coal being consumed in the burning. The fireman determines the heat by directing his sight to the mouths and top outlet of the oven; when the heat is reached, and before the fires burn hollow, the mouths are stopped up with ashes to prevent the cold air from cooling the oven too quickly.

The ovens are fired once a week, but can be fired easily three times in two weeks if so desired.

The manufacture of plain roofing-tiles can be conducted with a small capital, the process and requirements not being very intricate or expensive.

But to conduct the manufacture of all the tiles required for roofing, and the other articles generally produced in large tileries, requires a large capital and a thorough knowledge of the business in all its details.

In all the large tile-works, all the operations of manufacture are conducted under shelter, and a great variety of articles are produced, of which the following list is but a part:—

Chimney-pots, circulars for setting furnaces, etc., column-brick for forming columns, drain-pipes, drain-tiles, fire-brick, garden-pots, hip-tiles, oven-tiles, paving-tiles, pantiles, plain-tiles, ridge-tiles, and anything in the line required to order.

With the exception of fire-brick, the clay used for all these articles is the same; but for circular-brick, column-brick, kiln-brick, oven-tiles, paving-tiles, and paving-brick a certain quantity of loam is mixed with it, which for oven-tiles must be of a very good character.

To faithfully describe the manufacture of these various articles would increase the size of this chapter out of all proportion to its design. The principle of procedure is the same in eachcase, but no two articles are made or finished in a similar way, each requiring different tools and moulds.

The London tileries, which are the largest in the world, pay particular attention to proper preparation of the clay for the particular purpose for which it is to be used; there not being the same haste to get the clay into the kiln that is shown in some smaller manufactories.

The first stage in London tileries is the weathering, which is about the same as has been described for plain tiles, the object being to open the pores of the clay, separate the particles, and thereby compel it to absorb the water more readily in the process of mellowing.

This is accomplished by throwing the clay into pits, covering with water and leaving it to soften or ripen. The clay is now usually passed through the rollers and the stones taken out before it is put into soak, which is a term also used for the mellowing process.

The kilns used for burning the wares produced are usually conical in shape for more than one-half the height, about 40 feet wide at the base, and having a total height of about 25 feet from the bottom of the ash-pit to the top of the dome, which is

slightly convex. These kilns are quite expensive to build, eight thousand dollars being about a fair average; fire-brick being generously employed in the interior. This class of kilns is largely used for burning pantiles.

Before the pantiles are placed in the kiln, one course of burned brick is laid, herring-bone fashion, one and one-half inch apart over the bottom.

The tiles are then stacked upon this as closely as they can be, one course above the other. The hatchways are bricked up as the body of the kiln is filled. When the top layer is done, it is covered or platted with one course of unburned tiles laid flat; then on the top of these a course of burned pantiles is loosely laid. The hatchways are carefully daubed over, the fires lighted and kept gently burning for twenty-four hours, and then gradually increased, until at the end of six days they are left to die out, the burning being accomplished.

The class of goods which the kiln contains has a great influence upon the quantity of fuel consumed in a burning, chimney-pots, garden-pots, etc., not requiring so much as more solid goods.

In this country, the manufacture of roofing-tiles is a comparatively new industry; but it is rapidly growing in public favor, and their employment is becoming quite general.

Many large and costly, as well as small or ordinary dwelling-houses, church buildings, extensive work-shops, barns, etc., are covered with tile roofs.

With us, the tiles are usually of three colors, red, buff, and black. The color of the red tile is produced by the employment of clay containing a large per cent. of oxide of iron: this is sometimes present in the beds with fire-clays, which are the class usually employed for roofing-tiles; at other times, it is necessary to mix some foreign clay, containing a large per cent. of oxide of iron, with the material.

The color is made deeper and more uniform by rubbing the tiles with finely-sifted red moulding sand; this should be done while the tile is quite damp, so as to get the sand to stick or hold to the faces.

The buff-colored tile is made of nearly pure fire-clay, and it is slightly lighter in weight than the red tile.

The black tile is made by washing it over before burning with manganese dissolved in water, which, in the process of burning, is converted into a perfectly durable coating of great hardness.

The patterns usually employed with us for roofing-tiles are of several kinds; the large diamond, the small diamond shingle, round corner, round end, gothic, etc.

The large diamond tiles are 14 inches, the length of the diamond, and 8½ inches in the width; 250 cover one hundred surface feet, 10 by 10 feet, called a "square," and weigh 650 pounds.

They are fastened with two sixpenny galvanized iron or tinned nails. This kind of tile is used more than the other styles, as it is lighter in weight, and less in cost.

The small diamond, 6 by 10 inches, requires 500 to cover a square, and it weighs 600 pounds. It is nailed with five-penny nails, and is used more especially for towers, porches, dormer windows, and in side panels, for ornamental purposes.

The shingle tiles are the plain, flat tiles described in the commencement of this chapter; they are three-eighths of an inch thick, have two counter-sunk nail-holes, and are made of any size, not exceeding 6 by 12 inches; they can be had for round or square towers, dormer windows, etc., and the points are sometimes cut semicircular, octagonal, gothic, or pointed.

They have been largely used in the Eastern States, and on some expensive buildings for roofing and side ornamentation, as at the State capitol at Albany, New York, on which building they are wired to iron ribs.

These tiles are generally laid about 5 inches exposed to the weather, which requires about 480 for a square, weight being 1100 pounds.

The pantiles measure 12 inches in length by 6½ inches in width at one end, and 4½ at the other, and if they are lapped 3½ inches on the roof, 350 will be required for a square, which will weigh 850 pounds.

This kind of tile makes a strong roof cover, and can be walked upon without danger of breaking, and is especially suitable for workshops and factories; it is sometimes made with lugs to hang on to ribs, the use of nails being therefore avoided, which are liable to rust away where much bituminous coal is used. It is also made with nail-holes to secure it to the sheathing. Brick-making is now mostly done by machinery, and there is not the least doubt but that tiles of all kinds will also be generally so made both in this country and in Europe.

The roofing-tiles which have just been described are made by machinery by the firm of J. C. Ewart & Co , Akron, Ohio.

The machines which they employ were patented by Mr. C. J. Merrill about twenty-five years ago.

Roofing-tiles are now often made by running the clay through a stiff-clay machine, the blanks being formed thereby, and then pressing the blanks upon a hand or power press such as is made by C. W. Raymond & Co., of Dayton, Ohio.

BURNED CLAY AS ROOFING MATERIAL.*

Under the head of burned clay as a roofing material, the word tile expresses the material it is made of, how it is made, and its uses. "The Century Dictionary" defines the word tile as a thin slab of baked clay used for covering the roofs of buildings, etc. A thin slab of tin, iron, or metal of any kind is not tile. Tile is burned clay as a roofing material, and nothing else, and that is what I want to occupy your attention with for a few minutes.

Edward L. Morse published a series of articles in the American Architect, in 1892, on the older form of roofing tiles, that are exhaustive in tracing their history. He traces their use back to China, several thousand years before Christ, and says they were made even before the sloping roof was first used. Palm leaves, straw, and the bark of trees formed the first cover-

* From a paper read before the National Brickmakers' Association at Louisville, Ky., January 26, 1893, by John R. Elder, President of Clay Shingle Co., Indianapolis, Ind.

ings for sloping roofs, and then came terre-cotta tile, made in the form of bark, with the larger pieces curving upward, and smaller pieces to cover the joints. Relics of these ancient tiles are found in the art galleries in Berlin, Dresden and London. The articles are illustrated with cuts of tiles made in different countries, and it is a remarkable fact that tile are made and used in this country to-day of the same general form that was used four thousand years ago.

In his classification, Mr. Morse shows that the Normal (Asiatic) tile were used in the Orient, Ancient Greece and Italy, China, India, Greece and Italy, the Pan (Belgic), in England, Scandinavia, Belgium, Holland, Japan, Java and various modern countries; the Flat (Germanic), in Germany, Austria, Hungary, Poland, Switzerland, France and England.

In the shape and form of these tiles you will see the same shapes and forms most generally used to-day, both in Europe and America. It is shown that these old forms of tile are bedded in mud and clay—it is necessary in laying most of the tiles made at this day to bed them in cement. The most artistic tiles are found in China, Korea and Japan, where they are highly glazed, in different colors, with very elaborate finishings, making a very showy and ornamental roof.

The old form of tile were made of material the most enduring of man's fabrications, and the terra-cotta roof tile, when properly made, is, all things considered, one of the cheapest and most durable. Acting as a non-conductor, the upper portion of the house, under a tile roof, is warmer in winter and cooler in summer. Slate absorbs and transmits a great deal of heat. Shingles are short lived, and a menace in times of conflagration. With the best tile clays in the world, and an abundance of the unskilled labor usually employed in making tile, there is no reason why roofing tile should not come into common use in this country, as they have in all other parts of the world. These are the conclusions of Mr. Morse, and after an exhaustive investigation of tile roofing I must say that I fully agree with him.

In "the Encyclopedia of Architecture and Construction," A.

Rospide has an article on roofing tile in France, which gives a good description of the latest improvements. He divides his article on Roofing Material into four parts: first, Clay; second, Stone; third, Metallic; and fourth, Wood—giving the preference in the order named. In speaking of the manufacture of tile, he says it is still carried on just as it was before the development of machinery. The clay must be selected with great care, reduced to a paste, run into a plaster mould, then dried and burned. This necessarily makes the tile thick, and requires a great deal of trimming and handling. The simple and flat tile was long ago almost universally superseded by the lapping and interlocking tile. He says the following are requisites of every good roofing material:

1st. It must exclude moisture, which rots wooden framework.

2d. It must be capable of withstanding the forces of the wind, and must admit of provision for all expansion and contraction consequent upon variations in temperature.

3d. It must not overweight the trussing so as to increase the size of the supporting timbers.

4th. It must be fire-proof.

5th. The original expense should be consistent with the purpose which the construction is to serve.

6th. It should require but little care.

Every one of these conditions is fully complied with by the tile made under the patents of the Clay Shingle Company.

Louis H. Gibson, architect, spent years in France and Germany, investigating their manner of building, especially in constructing their houses so as to be secure from fires. He speaks in no uncertain way about burnt clay for covering houses. It is the ideal covering—the only material that is reliable, and will stand the test for centuries. He says:

"The arguments in favor of a tile roof are too old and too numerous to need anything more than mere mention. If we stop to think about it, we know that the roofing material in general use is far from satisfactory. Slate, at best, is a tempo-

rary roofing; it is readily affected by heat; so much so, indeed, that a little heat will expose all of the wood work of an ordinary roof to the action of fire. Shingles are as inflammable as it is possible to arrange the same amount of wood. Slate and shingles, as we know, are the general roofing materials. Tiles, being a clay product, afford protection to all wood work under them, in a perfectly satisfactory way. The heat does not affect the tiles in the least. Frost affects them much less than slate. The covering of a roof with tile practically means not only protection from the elements, but, as well, protection from conflagrations, or any unusual or dangerous degree of heat. Heat, as we know, cannot affect burnt clay products. This quality, together with its abilty to resist other elements of nature, renders it the ideal building material. Its qualities of this character are quite as apparent for roof covering as for other uses. For some reason, not easily understood, tile roofs have not been generally manufactured in America. While the field is open, and while there is a general demand for the material, it is not satisfied. There is a difficulty in securing a satisfactory tile roof at a moderate price.

"For the purpose of demonstrating the real value of tile roofs, I choose to go back to their history in France. There are many roofs existing in this country which are not quite one thousand years old, and those of the tenth and eleventh centuries are common indeed. What better evidence of their quality can be asked?"

In the western part of Indiana, in a small country town, lives a very intelligent old gentleman. He is a carpenter, and supports himself and family by work at his trade. He had traveled very little, his business did not allow him much time for reading, but he was a great thinker. He had an inventive mind, and understood the use of tools. As there were excellent clays in his town, he tried to form a tile for roofing houses. He spent all his spare time and money for years in experimenting. The forms he made were burned in a fire-brick factory near by. When he had got a good point he kept it, and changed, and altered,

and improved until he succeeded in getting what he believed to be just the thing. He wanted a tile that would be strong, light on the roof, that would be guarded at every point against sleet, rain and drifting snow; that would be wind, water and frost proof, and fire proof; that could be made by machinery at a small expense, and could be worked and burned without loss. After getting all these points to his satisfaction, he consulted a patent attorney and found his form and principle was new—that his title was patentable. He secured one patent, and followed that with others, until he now has six. Like most inventors, he had no money to manufacture his tile. He had neither money nor influence to seek the capital necessary. After several years the president of the railroad running through his town became interested in his invention, and through his influence the necessary capital was obtained. A factory was started. Again, time and money were spent in putting his theories into practical use. Tile were made—the factory was run successfully and profitably, and to-day some splendid buildings are covered with tile made at his little factory. He can show roofs equal to any in the world. Unfortunately, the factory burned, and has not yet been rebuilt, but four factories are now at work in different parts of the country, and before this year is out more tile will be made of his pattern, and under his patents, than in all the other tile factories in the United States.

Architects and others often wonder why more tile have not been used in the United States. This question is easily answered. In the first place this was a timber country, clapboards and shingles were easily made out of timber, and they formed a cheap roof that answered the purpose for a time. Then came slate, and tin, and galvanized iron, and felt, and gravel, that could always be obtained when wanted, were light and cheap. Tile, as made, were heavy, expensive, hard to get, and in consequence were only used on expensive buildings, that could contract for them in ample time. Many have tried to make tile, but the rule has been to follow the old forms of tile, and the old manner of making them, so that there was no

profit in it. Both Mr. Morse and Mr. Rospide, quoted above, confirm this fact. The manufacture of tile has not kept pace in advancement with that of any other branch of clay industry. The idea has been to invent a machine to make tile easily and cheaply, while the fact is, there is plenty of machinery exactly suited for the purpose. The brick presses of to-day can make tile just as easily as they can make brick, and the best of these are not expensive. I would not consider a re-press expensive that will make 4,000 tile a day, and cost but $225.00. The German press that forms the tile in plaster moulds is not what progressive Americans want. The application of our improved machinery in preparing clay, and forming tile, is a long step in the direction of increasing the use of tile, improving their quality and cheapening their cost.

So far as I have been able to learn, there are only five tile works in the United States. Three of these are in Baltimore and two in Ohio. Terra cotta works have made tiles on orders, but it is a branch they have not prepared for, and they only make them when they feel compelled to. There are more tile made by one factory in Ohio than by all the balance in the United States. This fact would indicate that making roofing-tile has not been profitable in this country, and this is probably true, as we find where any business is successful competition starts up all around it. In our opinion the reason the tile business has not been more successful is because the old form of tile, and the way of making them in the old country, has been followed in this. The tile is too heavy, has to be laid in cement, and the improved machinery has not been used in making them. And again, stocks have never been kept on hand to fill orders on short notice. When you think of the vast sums that are spent each year in buildings, and that fully one-twentieth of the cost of all these buildings is for the roofs, you can see what a business can be done, if the tile can be had at a reasonable price.

In speaking of the tile factories above, I did not include four that have been started within the last year to make tile under

the patents of the Clay Shingle Company. One factory has been started at Baltimore, one at Trenton, N. J., one at Chicago, and one at Denver. Before this year is out all these factories will be making tile on a large scale, and negotiations are now pending for several other factories.

In considering the value of roofing-tile the question of protection from fire, and insurance, enters largely into the account. In these days when so much money is spent in fire-proofing the insides of buildings with hollow brick walls, deadening the floors with terra-cotta blocks, and steel joists and girders, it seems like folly to put materials on a roof, the most exposed part of the building, that will not resist the least heat, but rather attract fire from adjoining buildings, and often when more than a square away. Many of you have had fires, and know what it means to be burned out; and all of you pay insurance, and know what a heavy tax that is. In Germany, where buildings are constructed under government inspection, with all possible protection against fire, and where tile roofs are universal, the rate of insurance is one-tenth of what it is in this country. A risk that will cost one dollar there will cost ten dollars here, and losses by fire there are as one to one hundred here. In the last seventeen years, in the United States, the losses by fire were $1,818,323,306.00—more than the present National debt. In the year 1891 the loss was $143,764,967.00, in 23,313 fires. Of these fires 44 brick and tile works were destroyed. 981 fires were caused by sparks from locomotives and flues, on which the loss was $4,506,184.00. 12,394 business failures were traced directly to the loss by fires in 1891. Last year $40,-600,000.00 of property was destroyed by fire that did not originate on the premises, or by exposure to adjoining property. The percentage of loss in 1891 that originated on the premises was $71\frac{8}{10}$, and by exposure, $28\frac{2}{10}$. This is a fearful record of loss by fire, and the worst of it is, every one of you have to pay part of it, whether the property was insured or not. This is only the money value of the loss, and if the loss in time and business, by men thrown out of work, was estimated,

it would probably be more than doubled. Now, as it is admitted and unquestioned fact that there is no material that affords so certain a protection from fire as burned clay, you see the value tile has *for roofing*. Nearly one-third the fires, and one-third the loss in 1891, was from outside exposures, that might and would have been saved if the buildings had been covered with tile. Can any stronger argument be used in covering houses with tile?

Another valuable quality in the clay roof covering is that it is a non-conductor. This is evidenced by the use of porcelain insulators on electric lines. They are considered just as good for this purpose as glass. Now it is as important in building a house to keep out the heat in summer as to keep it in in winter. It is the rule that the attics of our houses, and especially if covered with slate, are as hot as ovens; and as long as a single floor and coat of plaster only separate the attic from the sleeping room, the temperature in the latter nearly equals that of the former. Nothing so effectually overcomes this as a tile roof, which neither attracts the heat nor retains the frost. The sleeping rooms in a house covered with tile are always comfortable—cooler in summer and warmer in winter.

The day for boring auger holes with gimlets is past. In all mechanical business, and particularly in clay industries, in these days, it takes capital to start a business and carry it on. The profit is made to-day on the amount of business done—on the use of the best machinery, and appliances, and conveniences for handling and shipping. Little fish can't swim safely in streams where big fish live and thrive. The point I want to make is, that to be successful in any branch of the clay business, in these days, you must have money enough to get the best machinery, and to meet all bills until your business gets on a paying basis. This is particularly true in the tile business. Many have the idea that the roofing tile business is a small one—that it is like the drain tile business—a neighborhood affair. It is not. It is a business as large as you have the money and business brains to make it. No tile factory I know of in this coun-

try has been able to keep a stock on hand to supply immediate demands. It has been necessary to order the tile for the roof before the cellar was dug, and then often wait weeks or months, with the building exposed to the weather, before you get them. The consequence of this uncertainty and delay has compelled architects and owners to substitute other roof covering—they would not be deviled to death waiting. Tile will stand shipping—the business is a large and growing one, but it must not be started and carried on in the gimlet principle.

You have read in your papers of the trials and tribulations of the man who tried to run a brickyard. He had read about making brick in the papers, and therefore knew all about it. All he had to do was to buy a machine, start a yard, and the machine would make the brick. He tells of his troubles; the time lost, money lost, brick lost, temper lost, and even his religion lost, before he succeeded in becoming a good brickmaker. If this is true of brick, it is doubly true of tile. It is possible some of you have had experience in trying to make tile, and could tell interesting stories of how sanguine you were when you started in, and how disgusted you were when you started out. If you have not been there, others have. I have met them—plenty of them. I have heard of men that could tell you all about making tile—but their tile never got on the roof. I suppose I am talking to practical men, that can appreciate a practical business proposition. When I tell you that if you want to start in the tile business, buy experience and knowledge from the successful man, you will understand it. If the knowledge is of the right kind it is cheap at any price. It will save you much more than you pay for it. Experimenting costs a great deal more than practical knowledge and experience. The man that has the knowledge and experience has paid for it. You see the point?

Will tile sell? is a question that may be asked. I have been in a position to know they will. Of course tile, as compared with other roofs, is not a cheap roof, and will not be used on the cheaper class of buildings. But tile has qualities for roof-

ing no other material has, and if a tile looks well, has the fire and frost properties, can be laid at a small cost, is not too heavy, and can be sold at a reasonable price, every building that has valuable records and property to protect, churches, school houses, railroad depots, and elegant private residences, will use them. The trouble is not to sell them, but to have them to sell; so that architects and builders know they can get them, when wanted, without delay. I know what I am saying when I tell you the only trouble about selling tile is in keeping a stock on hand to supply the demand. Tile is the coming roof in the United States.

I have shown you from the best authority that there is no roofing material equals tile. Slate is the next best, and in comparing prices with an inferior article, you must bear in mind the relative qualities. The American Architect quotes prices on building materials. In looking at the quotations on slate in Chicago, to builders and contractors, the prices range from $5.50 to $14.00 per square. Red slate is $12.00 to $14.00 and unfading black and purple $7.10 to $9.00. Now the tile made under the patents of the Clay Shingle Company can be sold, at a good profit, for $8.00 per square, and can be laid on the roof as cheap or cheaper than slate; so you see the modern tile, made by machinery, having all the valuable qualities of the old tile, has the advantage in weight and price over the better class of slate. With these points in their favor, who can say that tile is not the coming roof?

GLAZING OF ROOFING TILES, ETC.*

Most varieties of clay, particularly those which burn red, permit, even when thoroughly burnt, the percolation of more or less water. Hence, it is frequently observed, that new roofing tile, especially when not previously soaked, permit the rain to pass through to such an extent that the water not only appears in drops on the lower surface, but in sufficient quantity to wet the floor below. To be sure, the interspaces in the clay

* From Waldegg's German Work on Brick and Tile.

are gradually closed by mud deposited by the water, whereby the tiles after some time become impervious. But the same mud also produces upon the entire surface of the tiles, especially if the latter are not perfectly smooth, a coating which takes up dust and dirt. Hence, it frequently happens that nearly all the tiles, particularly upon low roofs, are covered with thick moss, which retains moisture, and the tiles on such places must necessarily rot. The partial object of glazing roofing tiles is to prevent this evil.

Besides, the great roof surfaces of deep buildings, such as churches, are monotonous, they offering to the eye but little interruption. This is still more the case in brick-work, where the colors of the building are repeated in the roof. In the middle ages this evil was also recognized and overcome by covering the roof with glazed tiles of different colors. In building the Ludwig church, at Munich, V. Gaertner pursued the same course, and in covering the roof with glazed tile produced an effect which admits of comparison with a pearl-embroidered carpet.

Glazing consists in giving the exterior surface of the tiles a coating, which at the temperature required for burning is converted into a glass-like mass. Hence the glaze is a substance entirely different from the mass of the tile, and its durability and solidity depend much on the manner of its combination with the tile. The object of the glaze is, therefore, on the one hand, to decorate the tile, and on the other, to render its surface impervious. The glaze mostly consists of a lead-glass colored as desired by the addition of metallic oxides. For ordinary pottery the proportion of silica to lead oxide is about 1 : 2; *i. e.* mix about 1 part by weight of sand (frequently mixed with some clay) with double the weight of litharge or minium. The more sand in proportion to lead oxide is taken the more difficult to fuse the glaze becomes. Litharge or minium melts at a comparatively low temperature and in a melted state dissolves the admixed sand, forming with it, if the substances are pure, a white transparent glass. According to the constitution of the

sand a varying quantity by weight of it is at the same time dissolved by the melting lead oxide. If the sand is coarse-grained, so that the surface exposed to the attack of the lead oxide is a small one, as compared with the mass of the sand, far less of it will, of course, be in the same time dissolved than when the exposed surface is greater. Hence the finer the sand, the greater the quantity which will in the same time be dissolved by the lead oxide. For this reason sand as finely divided as possible is a chief condition in preparing glaze, because if the grain is too coarse, the entire quantity of sand is not dissolved, coarser or finer grains, according to the time during which the lead oxide was allowed to act upon the sand, remaining behind.

Of still greater influence than the fine division of the sand is its chemical condition, since its fusing point plays a very important role as regards the quantity which during the same time can be dissolved by the action of the melted lead oxide. Pure silica in the form of finely pulverized quartz, flint, etc., is not fusible, and hence will require the most time for solution by the lead oxide, because the latter will have to act upon a perfectly solid body. If silica in the form of a fusible mass be conveyed to the lead oxide, a much larger quantity of it will in the same time be dissolved, and it may be laid down as a rule, that a greater quantity of silica, of the same degree of fineness, will in the same time be dissolved by an equal quantity of lead oxide (as well as of other fluxes), the more readily fusible the mass is by means of which it is introduced. Nature furnishes us with an abundance of substances possessing all possible melting points, which, with a high content of silica, are more or less readily fusible.

There are sands with a very high content of silica which already slag (soften) at about 1000° C. and hence readily dissolve in fluxes. Such sands, highly valued for glazing purposes, are, for instance, found at Machlin, in Mecklenberg, and at Fuerstenwalde. These sands contain about 85 per cent. silica, 7.5 alumina, and 4 to 5 fluxing agents (ferric oxide, lime,

magnesia, and alkalies), and on account of their ready fusibility and physical constitution (they contain many fine scales of mica, which offer a large surface to the solution), they dissolve readily and rapidly in fluxing agents. Besides these there are many clays with a comparatively high content of silica which fuse more or less readily. There are clays fusing at from 1,000° to 1,100° C., which, in case such high temperatures are used in burning, yield by themselves good glazes, provided it does not matter as to color, and that the sole object is to make the articles impervious (earthy glazes for water-pipes, pottery, roofing tile, etc.).

In the great abundance of substances rich in silica and more or less readily fusible, which on the one hand are furnished us by nature, and on the other as waste (slag, broken glass, etc.), by certain industries, there are so many suitable for glazes that with some professional knowledge a suitable choice can be readily made, especially as the readily fusible fluxes (litharge, potash, soda, boric acid, etc.) offer means of bringing the fusibility of the selected materials within a narrow limit and thus exactly fit the fusing point of the glazing masses to the burning temperature of the kilns. With glazes for the purpose of decoration the conditions are much more difficult, the choice of substances through which the silica can be introduced being very limited. In this case not so much stress can be laid upon the ready solubility in fluxes as upon the purity of the materials. The naturally occurring substances rich in silica which are readily fusible, generally contain more or less iron by which they are colored dark. Hence if pure colors are to be obtained, sands, etc., containing iron have to be avoided and substances free from iron, but more difficult to fuse, selected. For glazes which are to serve for the pupose of decoration and show a determined color, sand free from iron (mica sand of the best quality, finely pulverized quartz or flint, etc.) will have to be used, and the proportion for the substances determined which is suitable for the burning temperature prevailing in the kiln. When a colorless lead-glass suitable for the special variety of

clay and the burning temperature employed has been found, the various shades of color are obtained by mixing the corresponding metallic oxides in proportions to be determined with the glaze.

For *dark-brown to black*, pyrolusite (peroxide of manganese) is used; for *green to black*, oxide of copper or chromium; *for blue*, cobalt oxide; *for yellow*, atimony oxide; *for red*, ferric oxide.

The application of the glaze to the tiles is as a rule effected by dipping, or to depressed places in ornamental or shape brick, or in architectural terra-cotta, etc., by means of a brush, the articles being dipped either in a dry state, or still better after having been burnt. If the surface of the tile is not sufficiently porous for the glaze to penetrate, a cementing agent (paste, gum arabic, etc.) is added to the latter to render its adhesion possible. The condition of the surfaces to be dipped or treated with the brush should be uniform, so that the glaze may everywhere adhere.

The principal defects shown by the glazes after burning are fine cracks. To prevent them, it is advisable to gradually decrease the content of fluxing agent (litharge, etc.) without, however, changing the composition of the mass, and thus make the glaze more difficult to fuse. The temperature must, of course, be increased, but fine cracks will thereby be entirely or almost entirely prevented. If, however, this remedy is not successful, *i.e.* if fine cracks still occur notwithstanding the utmost possible reduction in the content of fluxing agent in the glaze and a corresponding increase in the temperature, changes, as far as permissible, must be made in the raw materials. It should be endeavored to make the mass meagre with quartz sand or pulverized limestone (chalk) until the formation of fine cracks ceases. The so-called salt-glaze is produced by from time to time throwing salt into the kiln during burning. The salt vaporizes at a high temperature and produces a glaze upon the surface of the articles.

The constitution and preparation of the clay are of special

importance, particularly when the tiles are to receive a colored coating of glaze. In order to make the latter durable, it must enter into combination with the clay without the formation of fine cracks, bubbles, etc. The following mixtures which have been established by careful tests in the brickyards of Munich, fulfill these conditions with the glazes belonging to them, and may serve as guiding points.

I. DIFFERENT MIXTURES FOR THE TILE-MASS.

1.	Common clay	1 part by volume.
	Red clay	½ " " "
	Quartz sand	1 " " "
2.	Marl	1 " " "
	Quartz sand	1 " " "
3.	Marl	1 " " "
	Alum earth	1 " " "
	Chalk	1 " " "
	Quartz sand	1 " " "
4.	Common clay	1 " " "
	Red clay	1 " " "

Where there is a choice, the mixture given under 1 is to be preferred.

II. MIXTURES FOR GLAZES.

1. *Glazes for Nos. 1 and 2 of the tile-masses.*

Lead ashes	12 parts by weight.
Silver litharge	4 " " "
Quartz sand	3 " " "
White alum earth	4 " " "
Common salt	2 " " "
Powdered glass	3 " " "
Saltpeter	1 " " "

2. *Glazes for Nos. 3 and 4 of the tile-masses.*

Litharge	16 parts by weight.
Quartz sand	5 " " "
Powdered glass	4 " " "
Adamic earth	1 " " "

The intimate mixture of the ingredients of the tile-mass is, of course, the first requirement. For this purpose it is best to finely divide each ingredient by itself either by pounding or,

better, by rolling, then to pass it through a fine sieve, and after moistening the entire mass with water to intimately mix it by tempering or rolling. The constituents of the glaze are also passed through a fine sieve and, after being intimately mixed, fused in crucibles to gloss, which, after cooling, is reduced to a fine powder by grinding with water. The powder is then prepared as required for application to the tiles.

The flat tiles which are generally used in Munich are moulded in the usual manner, and after being carefully dried they are sharply burnt for the first time. To free the surface of the tile from dust and other impurities acquired in burning, and at the same time to test whether the tiles contain pieces of lime, they are dipped, *i. e.*, placed in water, for one or two days. Any lime present is thereby slaked and causes the tile to crack, which, of course, would also take place after the application of the glaze, but the latter would be lost.

The glazing mass mentioned under I, yields quite a white gloss, the whiteness of which may be considerably heightened by an addition of 20 to 24 lbs. of tin to every 100 lbs. of lead before reducing the latter to ashes. The coloring of both glazing masses is effected by the following additions, many tests being made as regards beauty, and especially durability:

Color.	To every 10 lbs. of glazing mass is added
Dark violet brown	½ lb. pyrolusite.
Violet	¼ lb. pyrolusite.
Green	¼ lb. copper ashes.
Pale blue	4½ drachms red cobalt ashes.
Golden yellow	½ lb. antimony.

These additions are not fused, but after pounding, passed through a sieve, and then ground fine. By adding more or less of them darker or lighter colors may be obtained. It may here be remarked that small tests should be made with all colors before coloring the whole mass of glaze, because the materials as obtained in commerce vary very much in regard to purity; the quantity of pyrolusite, for instance, required for the production

of one and the same color varying very much according to the source from which the material has been procured.

For glazing, the surfaces of the tiles are rubbed clean; the glaze is then applied with a brush, the tiles being held almost perpendicularly over the vessel containing the glaze. They absorb the glaze so quickly that soon afterward they may be replaced in piles. Formerly the glaze was applied dry, but glazing by the wet method is better. With some experience and skill one workman can glaze from 5,000 to 6,000 tiles a day. When the glaze is applied it is burnt in by a second slighter burning. In doing this special attention must be paid to the degree of heat in order to obtain uniform coloring, but further details regarding the operation cannot be given. An experiment made in Munich to prepare red tiles by coating the unburnt clay in a semi-dry, so-called leathery state, with pulverized reddle, then burning, and finally coating with a transparent glaze, did not succeed, since the glaze did not adhere and many tiles cracked. But a red glaze may be obtained by the admixture of a certain quantity of pyrolusite—between that required for dark violet brown and violet—and maintaining a fixed degree of heat, which can only be ascertained by experiments.

FIG. 234.

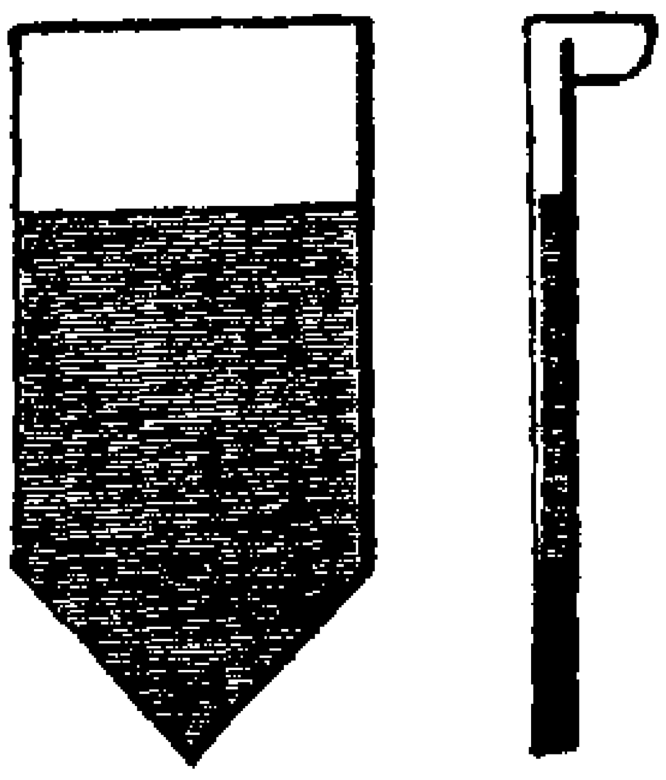


FIG. 235.

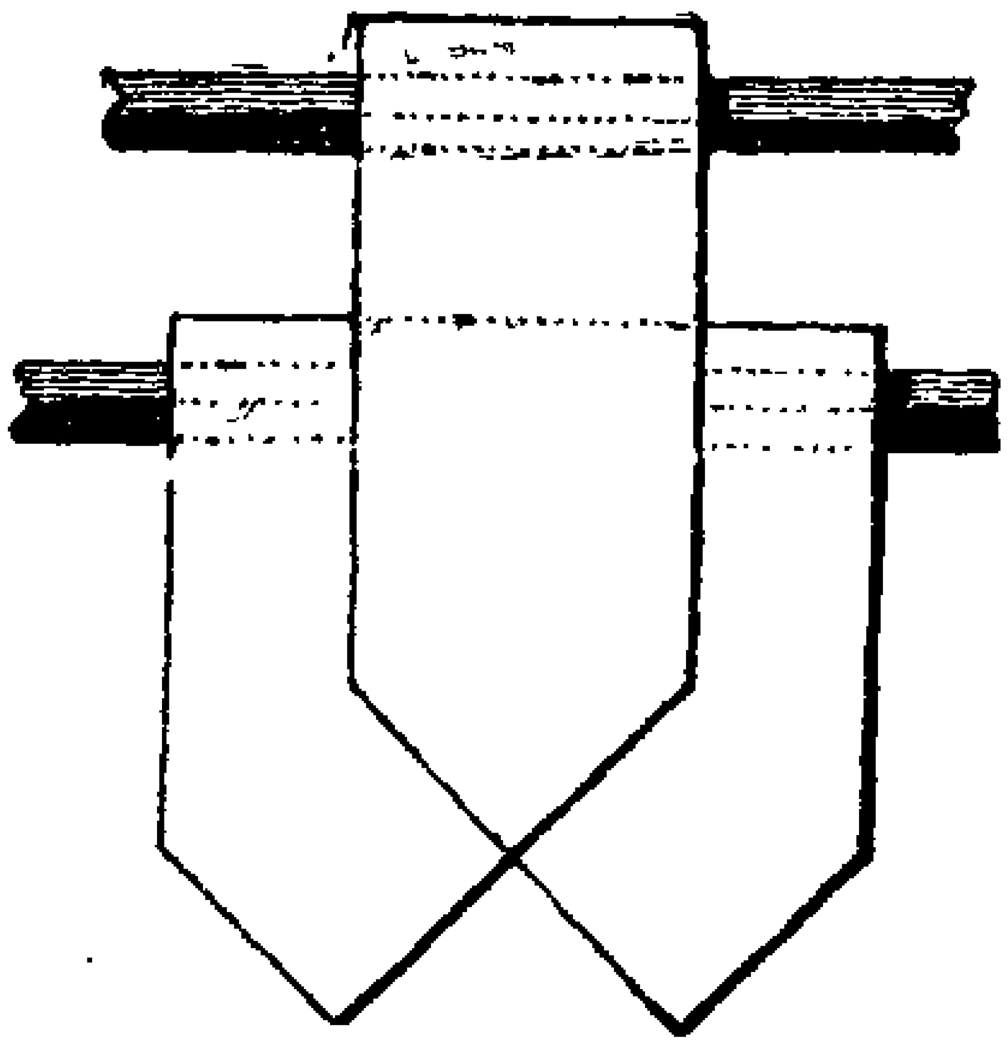
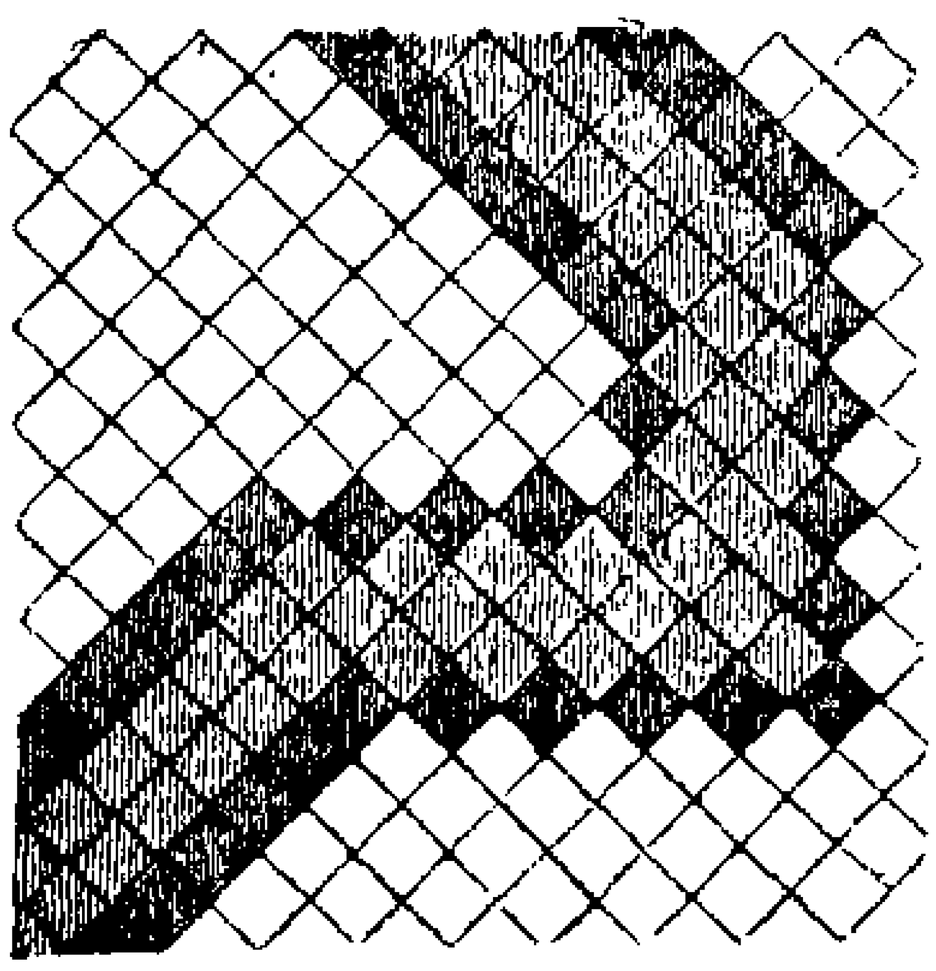


FIG. 236.



The illustrations, Figs. 234, 235, and 236, show the form and size of roofing-tiles, as well as the mode of tiling customary in Munich. Since after tiling the roof, the surface of the

tile which remain visible, form small squares with sides 4¾ inches long, it is possible to produce, by the use of different colors, designs which relieve the monotony of the surfaces. It may further be remarked that on account of the considerable height and the small size of the squares, the indentations of the horizontal and perpendicular lines cannot be seen, but appear as inclined lines.

For plain glazing (dark brown or black) roofing-tiles in a more simple manner, it is not necessary to first burn the tiles, but the glaze may be applied to the crude article. For the glaze it is best to use the Dutch directions, according to which 3 lbs. of pyrolusite are taken for every 20 lbs. of litharge, and so much clay is added that a ball formed of the clay floats in the glazing mass. For ordinary lead ore 6 per cent. pyrolusite suffices, and the glaze becomes perfectly black by adding 1.5 to 2 per cent. of copper oxide. In all compositions for glaze special attention must be paid that the mixture is not too readily fusible, so the tile itself has a chance to become hard by burning. Neither should it be too refractory, as otherwise the tile would be over-burnt before the glaze fuses. Hence, an accurate knowledge of the clay is necessary, and it should be determined by experiments how great an addition of one or the other kind of lead oxide it will bear in order to obtain the desired degree of fusibility. If pyrolusite is also to be added, the quantity of sand or silica must be sufficiently reduced in order to restore the proper proportions. It must also be remembered that pyrolusite makes the glaze far more refractory than silica or sand, which readily fuse with the lead to a glass, and that hence the quantity of the one cannot be exchanged for that of the other.

The above mentioned substances are, each by itself, reduced to as fine a state as possible, then weighed off in accordance with the above stated proportions and then ground, first each by itself and then mixed together, in a glaze-mill with water containing fine clay in solution, until they feel milky to the touch and nothing like sand can be detected. The rapid pro-

gress of this operation is chiefly dependent on the quality of the mill-stones and the arrangement of the mill. Ordinary glaze-mills are of fine sand-stone, hard lime-stone, or granite.

Before applying the glaze, the surfaces of the raw tiles are rubbed clean, to prevent the glaze from being contaminated by sand or dust. When sufficient tiles have thus been prepared, the workman places himself between the tiles and a frame. Upon a bench in front of him stands a shallow vessel of a wide circumference filled with glaze. This vessel is called the glaze-back and may be of wood or, still better, of earthenware. After stirring the glaze with a large wooden spoon, the workman, taking with the left hand a tile by its upper portion, and holding it almost perpendicularly over the glaze-back, places the spoon filled with glaze about 1½ inches below the upper edge of the tile and moves it from the left to the right, allowing the glaze in the spoon to run over the tile. If the glaze is of the proper consistency it is, in this manner, very uniformly distributed over the entire surface of the tile. A test with the finger-nail is from time to time made to see whether the glaze has still the requisite thickness, water or thicker glazing mass being otherwise added. The tiles absorb the glaze with such rapidity as to permit of them being soon afterward replaced in piles. The finer the glaze has been ground, the better it remains suspended in the water and the more rarely it requires to be stirred up from the bottom. A further reason for the necessity of grinding the glaze as fine as possible is that otherwise the pyrolusite does not thoroughly mix with the lead ore, which causes the appearance of streaks and stains after burning. With some experience one workman can coat 5,000 to 6,000 tiles with glaze per day.

Regarding tiles, the question whether it is more advantageous to glaze the crude or burnt articles is not so easily answered as for finer clay ware. When the tiles have been properly set in the kiln and the fire is properly conducted, the refuse by breakage, cracking, etc., should not be considerable. But with tiles the mishaps by fusing and baking together are

more dangerous. With well-constructed kilns the first should scarcely happen, especially when heating with small fires and the coal cannot directly act upon the tiles. The latter may be avoided: 1. By not applying the glaze too thick; 2. By the upper portion of the tile, where the knob of its neighbor leans against it, being left free from glaze; 3. By setting the tiles as perpendicularly as possible so that they touch neither with their surfaces nor with their lateral sides, and so firmly that they cannot turn over during burning; and 4. By wiping off with the hand the greater portion of the glaze from the base of the tile, so that there is no danger of their baking together on that point. With a second burning the tiles are, however, exposed to the same mishaps, and the consumption of double the quantity of fuel is mere waste.

The following process may also be recommended as the most simple glaze. Scatter finely sifted unburnt lime and ashes over the half-dried tile, rub in well, and then allow the tiles to dry further. This mixture is a slight fluxing agent and produces a glaze upon the surface.

Glazing with salt is effected by throwing the salt in the kiln, when burning is finished so far that the kiln is to be closed for cooling off. Since by this process a uniform glazing of all the tiles cannot be effected, it is preferable to prepare a supersaturated solution of the salt in water and apply it to the tile before setting them in the kiln.

Regarding the setting of glazed tiles it may be remarked that a kiln should never be entirely set with them; because even with the best kiln it is impossible to distribute the heat so uniformly as to avoid fusing together, if it is insisted upon to everywhere fuse the glaze.

RAW GLAZING OF DUTCH TILES.

The object of raw glazing of Dutch tiles is to apply the glaze to the green tile and to burn the clay mass and glaze in one fire. All endeavors previously made to introduce raw glazing failed on account of the glaze readily falling off from the un-

burnt tile when touched; further, on account of the glaze contracting in burning and leaving unglazed places. These difficulties are overcome by the following process:

Glue-water of about 5° Bé. is poured over the tile, which must be air-dry and free from dust; the tile is then allowed to dry in the air for a few hours; potters' glazing wash is then applied to the tile thus prepared.

MEISSEN MASSES FOR DUTCH TILES.

Chamotte Mass.—One part by measure of chamotte, 2 of Lothain clay.

White Covering Mass.—Twenty pounds of Kaschka clay, 10 pounds of elutriated kaolin, and 5 pounds of feldspar.

Silver Gray Covering Mass.—One hundred and twenty-five pounds of kaolin, 75 pounds of Lothain clay, 55 pounds of Mattowitz clay, 0.5 pound of pyrolusite, and 7.5 pounds of smalt.

Fawn-Color Covering Mass.—Fifty pounds of Lothain clay, 25 pounds of Mattowitz clay, 4 pounds of pyrolusite, and ½ pound of smalt.

Yellow Covering Mass.—Fifty pounds of Lothain clay, 12.5 pounds of Wahlstadt clay, and some ordinary clay.

Brown Covering Mass.—Fifty pounds of Lothain clay, 10 pounds of bole, and 7.5 pounds of pyrolusite.

Green Covering Mass.—Ten pounds of Kaschka clay, 2½ pounds of Lothain clay, copper scales 2 to 3 pounds.

Blue Covering Mass.—White covering mass of the composition given above 100 pounds, smalt 20 to 25 pounds, and white chamotte, 50 pounds.

Mass for Mending before Glazing.—Glowed kaolin, 1 part by measure; feldspar, ¾; whiting, ¾; crude kaolin, 2.

Cheap Glaze Especially for the Colored Mass.—One part by measure of litharge, and 1¼ to 1½ of sand.

Finer Glaze for White Tiles.—White quartz sand, 24 pounds; litharge, 10 pounds; chalk, 6½ pounds; borax, 6 pounds; soda, 3 pounds; glowed white clay, 3 pounds; feldspar, 2½

pounds, and ½ ounce of cobaltic oxide. The mixture is fritted and then ground together with 60 pounds of red lead.

GLAZES FOR DUTCH TILES.

Kraetzer recommends the following compositions:

1. *White Glaze.*—Stir together 120 parts of concentrated solution of soda water-glass and milk of lime (7½ to 12 parts of lime) until the mixture is perfectly dry; then pulverize, grind and sift. The crude tiles are either brushed over with water-glass solution or the powder moistened with water-glass solution is applied as glaze and burnt. Potash, 100 parts; Chile saltpetre, 12½, and lime, 25, fused together, pulverized and mixed with water-glass solution, may be worked in the same manner.

2. *Deep Red Glaze.*—Finely pulverized white glass, 15 parts; pulverized borax, 7½; whiting, 5; Chile saltpetre, ¼; purple of cassius, 2½; fused together, pulverized and applied with water-glass solution.

3. *Dark Red Glaze.*—Glass, 24 parts; soda, 12; borax, 9; red lead, 9; Chile saltpetre, 4½; antimony, ⅜; purple of Cassius, 3; sal ammoniac, 3; fused together, pulverized and applied with water-glass solution.

4. *Azure Blue Glaze.*—Glass, 16 parts; soda, 5⅓; borax, 4; calcined bones, 2⅔; Chile saltpetre, 1½; cobaltic oxide, 1⅓; fused together, pulverized and applied with water-glass solution.

According to other statements, a good glazing mixture is obtained by carefully burning 60 parts of lead and 40 of tin. Fuse 100 parts of the ash thus obtained with 50 parts of sand free from iron, 50 parts of common salt, 20 of feldspar, 6 of saltpetre, and 6 of litharge. The fused mass is ground. If for some masses this glaze should prove too liquid, so that it runs off, take for the above mixture 60 parts of sand and 25 to 30 parts of feldspar.

GLAZES FOR ROOFING-TILES.*

Roofing-tiles are, as a rule, only glazed when it is expected to impart to them thereby greater resistance to the weather, or to produce certain decorative effects. Hence dark glazes are frequently demanded, if only for the reason that, as regards roofing-tiles, we have generally to deal with quite dark-colored clays. But such tiles should only be glazed if they possess the degree of solidity absolutely required for it. It is well known that slightly burned tiles, when glazed and exposed to the weather, scale off, as a rule, in a short time, and hence are not improved by glazing. It is, therefore, necessary that tiles which are to be glazed must be burned hard, at least, medium hard; or still better, that they are clinkers. Many proprietors of brick-yards seem to be of the opinion that tiles may be burned slightly, and then provided with a glaze to make them more durable. Such, however, is not the case. If a tile is saturated with water and allowed to freeze, it will be observed that small sticks of ice are forced from all the small pores, which is due to the expansion water undergoes in freezing. The sticks of ice forced out will be the thinner, the finer the pores, and the thicker, the coarser the pores. This will be especially observed in calciferous washed clays. The ice, under pressure, acts like a fluid, and passes out through the fine openings. Now, if these openings are covered by a glaze which does not firmly adhere to the tile, and the quantity of water is quite large, entire portions of it are forced off. Hence, since it is generally endeavored to burn glaze and tile in the same burning, the fusing point of the glaze must be arranged in accordance with the slagging point of the clay. Now the glazes themselves, especially the readily fusible ones, are not always capable of resistance, but are frequently decomposed by atmospheric influences. Thus, for instance, alkalies are lixiviated from the layer of glaze by the influence of the atmosphere. The layer of glaze

* An address delivered before the General Convention of the German Society for the Fabrication of Brick, Clay Wares, Lime and Cement, by Prof. Dr. H. Seger.

is thereby loosened, becomes mottled, changeable, full of cracks, and finally the entire glaze scales off. Such glazes will have to be examined, as is done with glasses in which the action of the atmosphere upon the surface has also to be inquired into. Professor Weber has proposed an excellent method of testing glasses as to their power of resistance against the atmosphere, which I have also used for glazes. Professor Weber proceeds from the fact that the atmospheric influences are much stronger by taking substances which act more energetically than carbonic acid and water. He therefore places the glasses under a bell in which is a vessel with concentrated hydrochloric acid. The acid begins to etch the surface much more rapidly than the carbonic acid of the air, and if the glass is destructible, such destruction takes place in a very short time by a slight efflorescence of separated silica showing itself upon the surface.

The nature of the glazes to be used depends on the temperature they are to sustain. With low temperatures, glazes containing lead will have to be used, because there are no glazes free from lead for the lowest temperatures employed. The glazes used in pottery are simple lead silicates. They are the most readily fusible glazes and occur also in the manufacture of tiles.

As regards their content of silica they vary from a sesquisilicate to a trisilicate, which at the same time contains alumina; the richer in silica, the more refractory they are. The composition of the most readily fusible and the most refractory lead glazes may, according to the ratio of the weight of the separate constituents, be represented as follows:

Readily fusible glaze—1.0 x 223 oxide of lead, 1.5 x 60 silica.

Refractory glaze—0.1 x 94 potash, 0.2 x 56 lime, 0.7 x 223 oxide of lead, 0.3 x 101 alumina, 3.0 x 60 silica.

The glazes employed will, as a rule, lie between these two compositions. The degree of refractoriness of the glaze which is required will of course have to be taken into consideration, and hence, these numerical values may and must be extremely

varied. When in glazing tiles color, and especially a dark color, is the chief requisite, the clay at the disposal of the manufacturer will, as a rule, be utilized, in receiving simply an addition of oxide of lead, whereby the action of the ferric oxide in the clay as a yellow or broom coloring agent has to be taken into consideration. No other substances require, as a rule, to be added. Boric acid, especially, should be avoided, since glazes containing boric acid have always to be fritted in, which cannot be recommended for glazing tiles, since the glaze should be as cheap as possible. For colored glazes the color of the tile must first be covered with a white layer, glazes containing tin being best for this purpose. The application of a white-burning clay to the clay cannot be recommended. The average composition of those white enamels, will also serve for the preparation of ordinary faience. Dutch tiles, etc., may be given as follows: 9.5x94 potash, 0.8x223 oxide of lead, 0.2x 101 alumina, 2.0x60 silica and 0.5x150 oxide of tin. Sometimes more of one and less of another constituent may be required, but generally speaking the above is an average composition. The oxide of tin makes the glazes opaque and white. Any color desired may be produced by adding certain metallic oxides, for instance, oxide of cobalt up to 3 per cent.; oxide of copper up to 4 per cent.; peroxide of manganese up to 8 per cent.; ferric oxide up to 4 per cent.; oxide of uranuim up to 5 per cent.; antimonate of lead up to 10 per cent.

The above-mentioned lead glazes comprise, according to their composition, a scope of from about 932° F., dark-red heat, to 2,100° F. (Seger's cone No. 1). Above these temperatures lead glazes cannot well be employed, because they possess the great disadvantage of the oxide of lead readily volatilizing under the influence of the fire-gases, whereby the glazes become more acid and refractory, and no longer turn out bright. The longer the glazes remain in the fire the more apparent this evil becomes, and the stronger, the higher the temperature which is used. The glazes containing tin fuse at about the melting heat of silver, sometimes above and sometimes below it, according to their composition.

The most important glazes for roofing tiles are those free from lead. They are employed in the form of clay or clay-like masses, which are applied to the tiles and then burned on. It is, however, impossible to give the clays such a composition that the glazes fuse at an early period, a certain degree of heat being required for their fusion. A glaze of 0.2 equivalent potash, 0.8 lime, 0.3 alumina, 0.2 ferric oxide and 3.0 silica, fuses at about 2100 degrees F. (Seger's cone No. 1), this being the lowest fusing point for such glazes which can be attained; they frequently require a temperature represented by Seger's cones Nos. 6, 8, and sometimes 10. The glazes which, at least for low temperatures, must always contain iron, appear by fusing as a black layer, the surface of which, when for some time exposed to atmospheric influences, acquires a brown color, about that of an ordinary pot glaze. By heating this glaze free from lead under the influence of reducing gases, the ferric oxide is converted into ferrous oxide, and the layer of glaze appears black. By adding to the glaze some oxide of manganese, copper, cobalt, etc., it also acquires a black color, which is permanent and does not assume the yellowish coloration of iron glazes. They consist of ferrous silicate, corresponding to finery cinders. They are produced by the application of ferric oxide, and sand, generally inpure ferric oxide (yellow ochre) mixed with sand. The ferric oxide (ochre) at disposal for this purpose always contains sand, and sometimes more sand is added. If the ferrous silicate is burned with the exclusion of reducing gases, it acquires a reddish brown color. But if it is burned in a reducing atmosphere, it becomes pure black, and the surface then assumes a slate-gray color. It does not completely fuse to a liquid mass, but in fact only frits together. The glazes are never quite bright and lustrous, but always dull, which is however, desirable. According to its composition and the proportion of ferrous oxide to silica, the fusing point of this glaze may be as high as that represented by Seger's cones Nos. 10 and 11, or as low as that represented by cone No. 2.

I have recently occupied myself much with glazes, and have

found that their higher or lower fusing points are chiefly dependent on their content of silica. The glazes richest in ferrous oxide are by no means the most readily fusible. The lowest fusing point is possessed by glazes which represent a ferrous bisilicate (72 ferrous oxide, 2x60 silica), the refractoriness increasing with an increase as well as decrease in the content of silica. Somewhat more readily fusible than the pure ferrous oxide combinations, are those which, besides ferrous oxide, contain manganous oxide. However, even such a glaze cannot be applied to a tile which has not been burned at at least a temperature represented by Seger's cone No. 3. Such mixtures which, besides ferrous bisilicate, contain considerable quantities of other substances, especially alkalies, lime and alumina, may be more readily fusible, but lose thereby their peculiar character—the slate-gray color—and are converted into glassy, bright, black masses.

It is certain that for glazes free from lead the fusing point should not be lower than Seger's cone No. 1 (2100 degrees F.), and for those containing lead not higher than that temperature. This establishes a definite boundary between these two kinds of glazes, which cannot be passed. Hence, if a chemist is required to compose a glaze free from lead, or furnish a receipt for a slate-gray glaze for a tile which cannot, without danger, be heated above 1832 degrees F., it will be impossible for him to comply with the demand.

THE MERRILL ROOFING-TILE MACHINE.

The practical operation of the Merrill roofiing-tile machine, shown in Figs. 237 to 248, is as follows: The wheels are made to revolve in direction of the arrows; a certain portion of clay is placed in the dies which, by the corresponding curvature of their faces, when the dies begin to move, press the clay at one corner or end by a rolling motion, thereby packing the clay into all parts of the dies, and forcing the surplus clay out at the opposite corner. While the clay is thus being pressed the nail-holes are punched, the punches being forced out by the head

or bar coming in contact at the proper time with cam *A*, Fig. 237, indicated by the dotted lines, attached to the inside of the standards, one on each side of the wheel, over which the projecting ends of the head slide, thereby forcing out the punches into the dies, and perforating the clay. The moment that the holes are punched the punches are withdrawn into the wheel

FIG. 237.

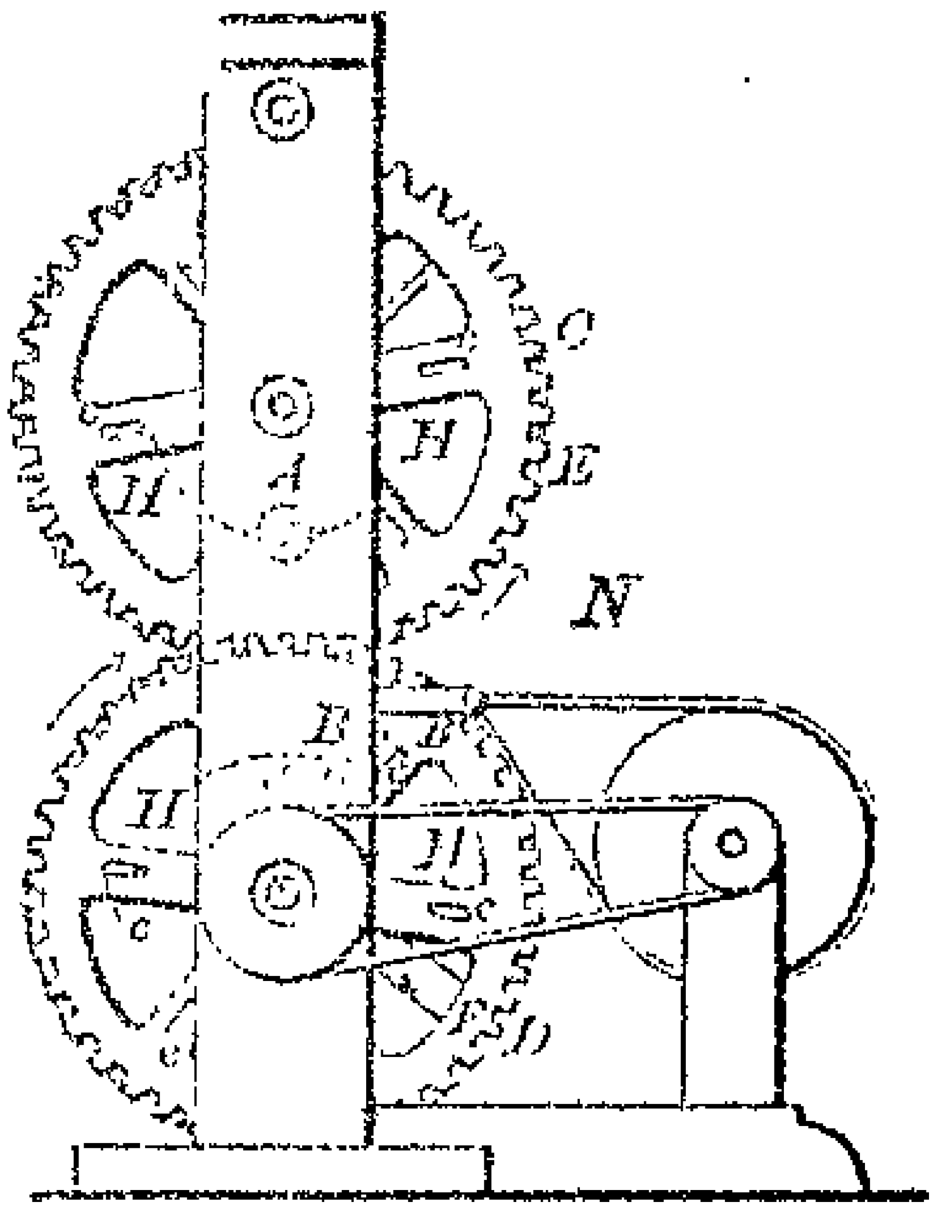


FIG. 238.

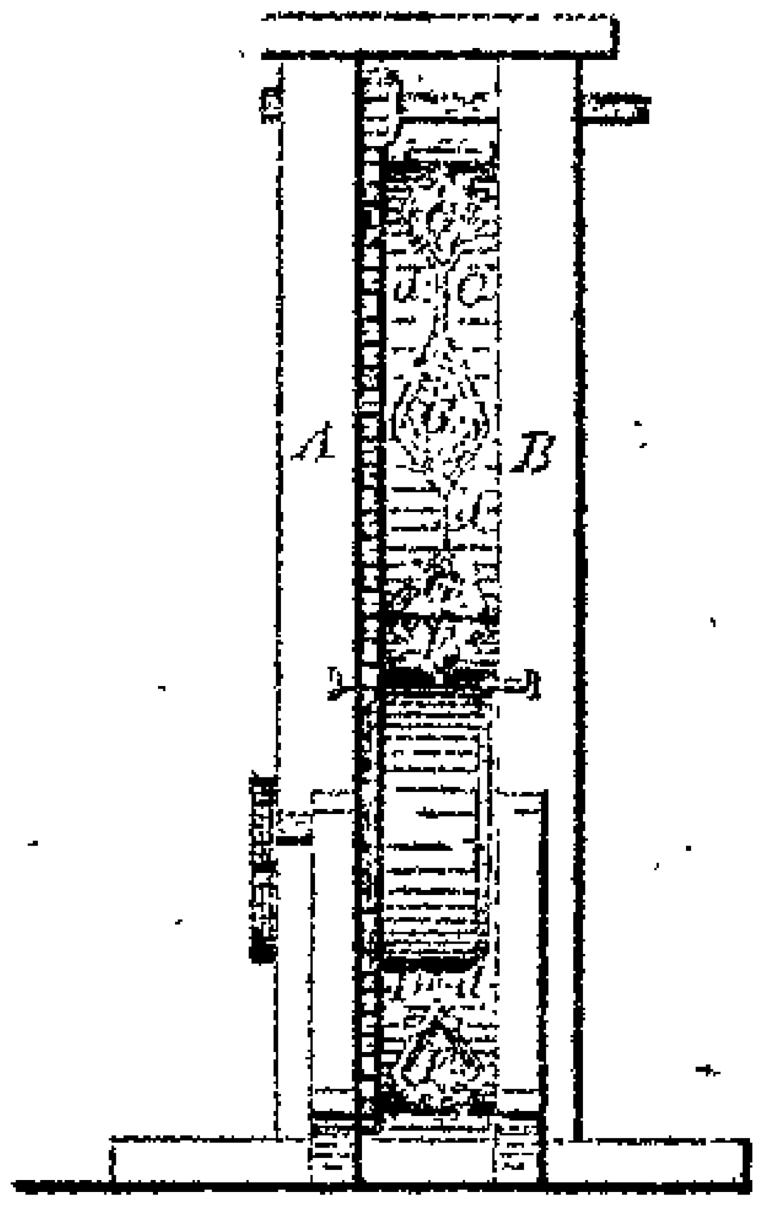


FIG. 239.

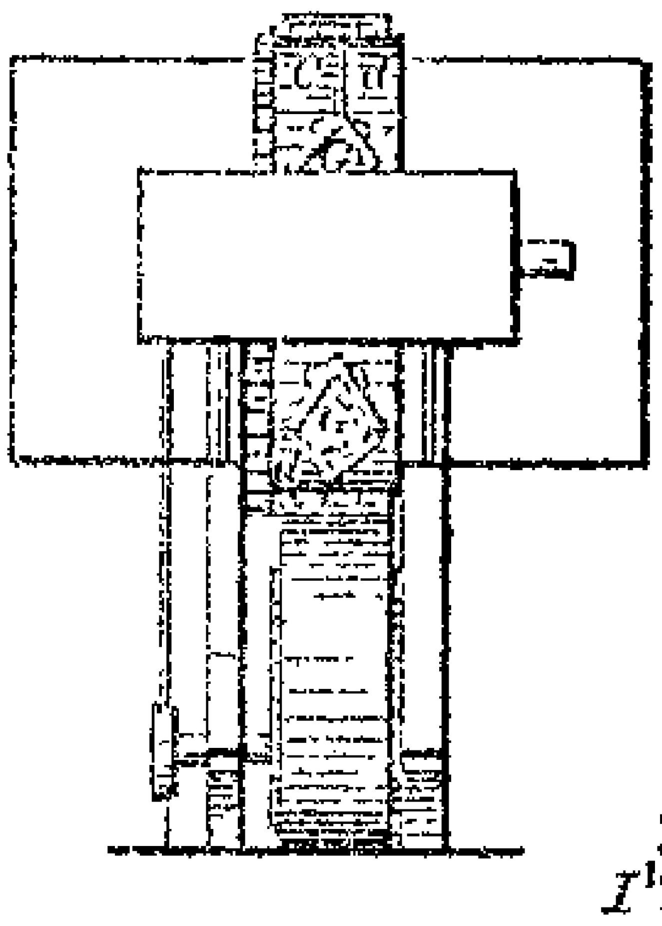
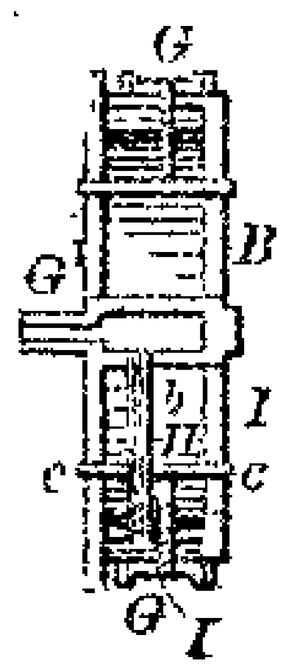


FIG. 240.



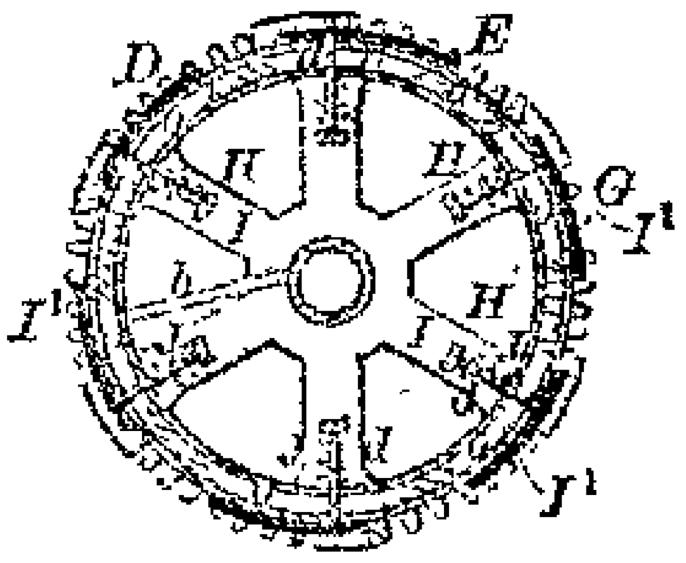


FIG. 241.

by the springs. At this time the tongue at the bottom of the lower die is forced out by the projecting ends of the head *H* coming in contact with the side cams *B*, Fig. 237, thereby forcing outward the rod *d*, which so far pushes out the tongue as to allow the end of the tile thereon to fall upon the endless apron *N*, Fig. 237, whereby it is moved away. The use of the

steam in connection with the dies is to heat them so as to relieve the clay after the tile receives the pressure.

Fig. 237 is a side elevation of the machine. Fig. 238 is an end elevation. Fig. 239 is a plain view. Fig. 240 is a detached transverse section. Fig. 241 is a detached vertical section. Figs. 242, 243 and 244 are detached sections. Figs. 245, 246 and 247 are views of a tile made by the machine. Fig. 248 is a detached section.

The construction of the various parts of the machine is as follows:

In the drawing, Fig. 238 *A B* represent a pair of standards,

FIG. 242.

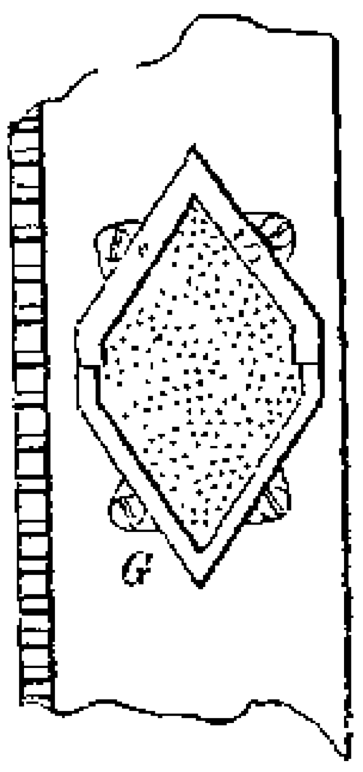


FIG. 243.

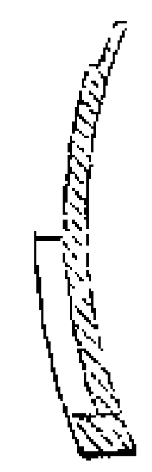


FIG. 244.

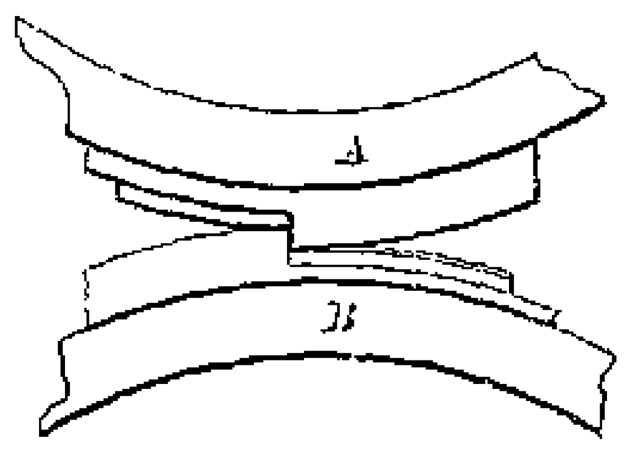


FIG. 245.

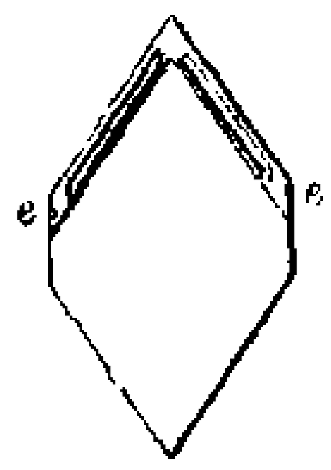


FIG. 246.

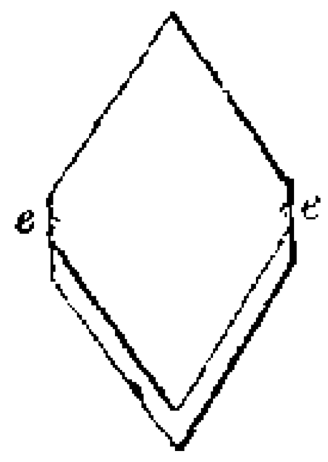
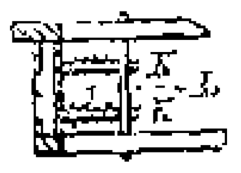


FIG. 247.

FIG. 248.



in which are journaled two wheels, *C D*, which engage each other by the gearing *E*. Under each of the dies or moulds is formed a steam-chamber *O*, Fig. 241, into which steam is admitted through the pipe *b*. One end of this pipe terminates in one of the chambers, and the opposite end terminates in the hollow shaft G^1 of the wheel, into which steam is received from the boiler. The several steam-chambers are connected to each other, for the transmission of steam, by a pipe *d*, Figs. 238 and 239, extending around the wheel from one chamber to another. The purpose of this chamber will presently be shown. In the

faces of the wheels referred to is arranged a series of dies or moulds, *FG*, which are so constructed as to give the desired shape to the article to be made, which, in this machine, is a roofing-tile. Detached views thereof are shown in Figs. 245 and 246, which give a view of both sides of the tile. The upper and lower dies are constructed substantially alike, differing only in the fact that in the bottom of each of the lower dies is placed a metallic plate or tongue I', of the same form as the inside of the die, and upon which the clay is placed and prepared, and whereby the pressed article is forced out from the die by raising the tongue, as will presently be shown. The tongue referred to is raised out of the lower die by a rod *d*, Fig. 241, one end of which is secured to the tongue, whereas the opposite end is secured to a bar *H*, Fig. 241. The two ends of this bar project through slots *c* in the arms *I* of the wheel, in which the bars slide for operating the tongues of the dies. *J*, Fig. 241, is a spring surrounding the rod *d* referred to, the purpose of which is to retain the tongue within the die. Fig. 242 represents an enlarged detached view of one of the dies, the face of which, and also the face of the tongue, being etched or otherwise made with a roughened surface, so as to confine small portions of air between these surfaces and the clay, which air, when the pressure is removed, will expand and raise or loosen the clay from the roughened surfaces. Fig. 244 represents detached sections of the upper and lower dies, with their relation to each other while pressing the clay between them; and Fig. 243 exhibits a longitudinal section of a die, all of which shows the form of the dies for making the tiles, as in Figs. 245 and 246. In the upper wheel *C*, there is an arrangement similar to that in the lower wheel for ejecting the tile, the purpose of which is to punch the nail-holes *e* in the sides of the tile, and which arrangement consists of the two punches *K*, Fig. 248, attached to sliding head or bar *D*, the ends of which project through slots of the arms of the wheel.

MACHINE FOR MOULDING ROOFING-TILE FROM PLASTIC CLAY.

The machine shown in Figs. 249 to 252 is especially designed for the formation of roofing-tile from plastic clay.

The main features of the invention consist of a series of similar lower dies attached to a revolving horizontal table, and brought successively beneath the upper dies; the latter consist of two parts, viz., an outer shell, which forms the edge of the tile, and an upper die, sliding within the shell, and which forms the upper surface of the tile, each attached to suitable slides, and adapted to move independently with a vertical reciprocating motion. In combination with these elements, and moved by the same machinery, is also an automatic feeding apparatus.

Figs. 249, 250 and 251 represent, respectively, a side elevation, a front elevation, and a plan of the tile-machine; and Fig. 252 a perspective view of the dies and shell on an enlarged scale.

The main part of the machine is attached to and supported by the frame *A*, which stands upon the legs *B B*. Journaled in the upper part of the frame is the shaft *C*, turned by the pulley *D*. On the front of this frame *A* are cast or attached suitable guides *e e*, within which moves the slide *E*, carrying on its lower end the upper die *F*, and moved with a vertical reciprocating motion by the cam *G*. Upon the outside of the guides *e e* is fitted another slide *H*, also having a vertical reciprocating motion, moved by the cam *I*, and carrying the shell *J*. The lower dies *K K* are attached to the platform *L*, which is keyed to and turned by the shaft *M*. The platform *L* rests upon an annular bed *N*, attached to and supported by the frame *A*, and the upper surface thereof, being planed smoothly, affords a sliding seat, upon which the platform *L* revolves.

In practice it will be found convenient to have both the annular bed *N* and lower die *F* cast hollow, and charged with steam, when in use, to facilitate the separation of the dies from the tile after the latter is pressed. Upon the shaft *C* is an eccentric-cam *O*, connected to a crank on one end of the shaft *Q* by the rod *P*; and upon the opposite end of the shaft *Q* is a

crank-arm *S*, which is connected by a rod *s* to, and moves a loose collar *T* on the shaft *M*.

This collar *T* carries a pawl *t*, which engages the ratchet *U* on the shaft *M*, and thereby the cam *O* causes, at each return stroke of the upper die *F* and shell *J*, a partial revolution of

FIG. 250.

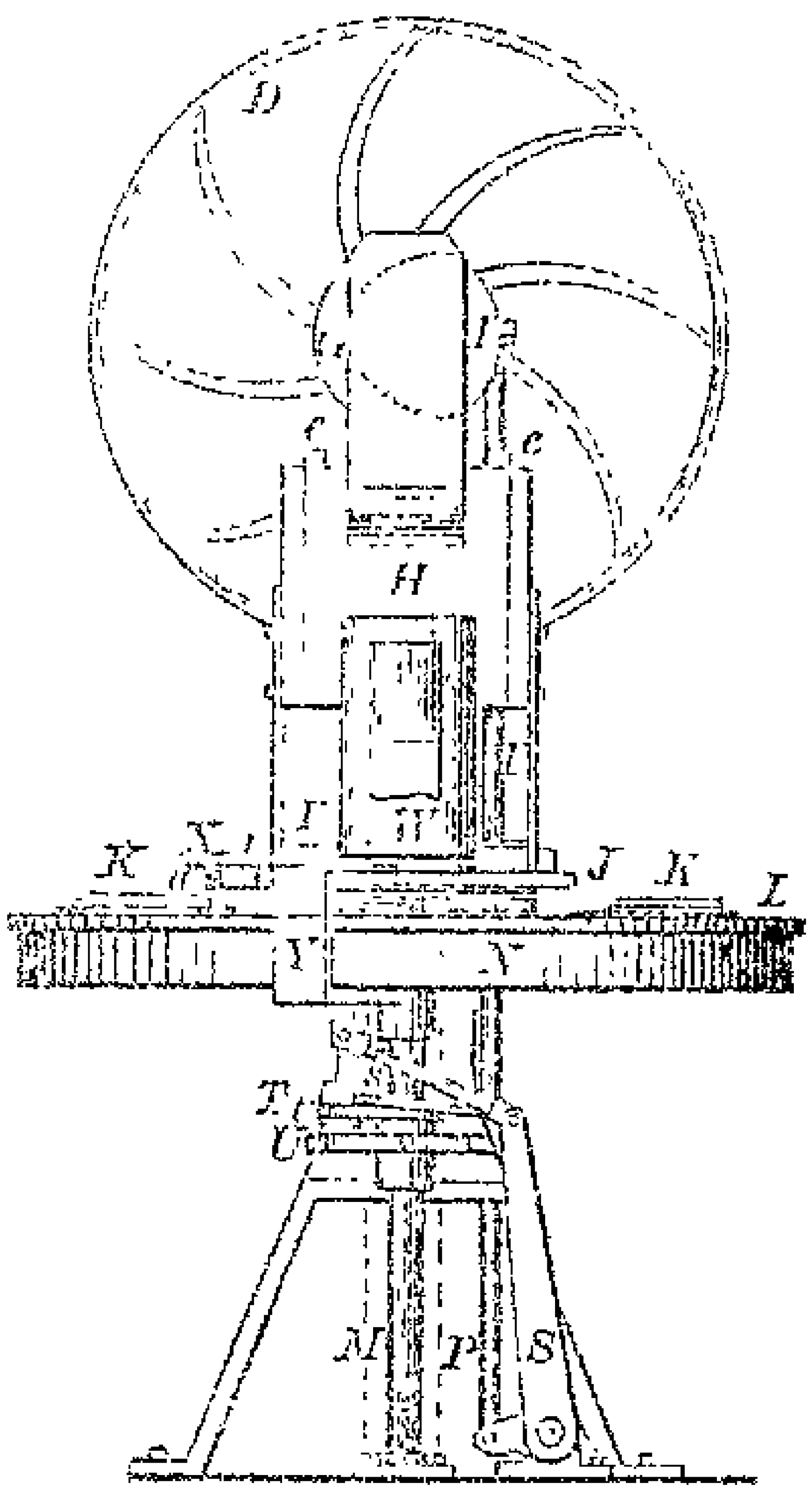


FIG. 249.

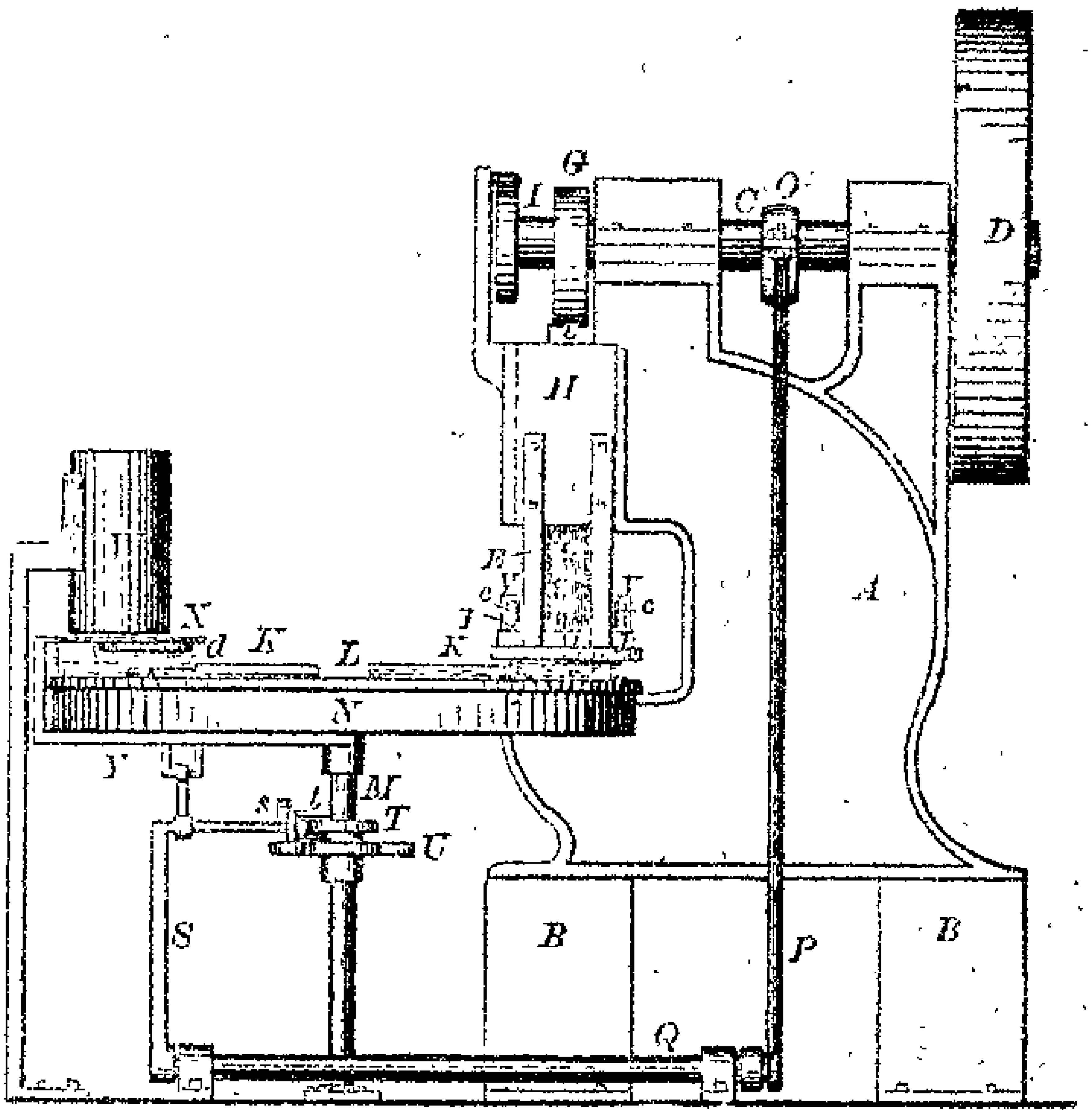


FIG. 251.

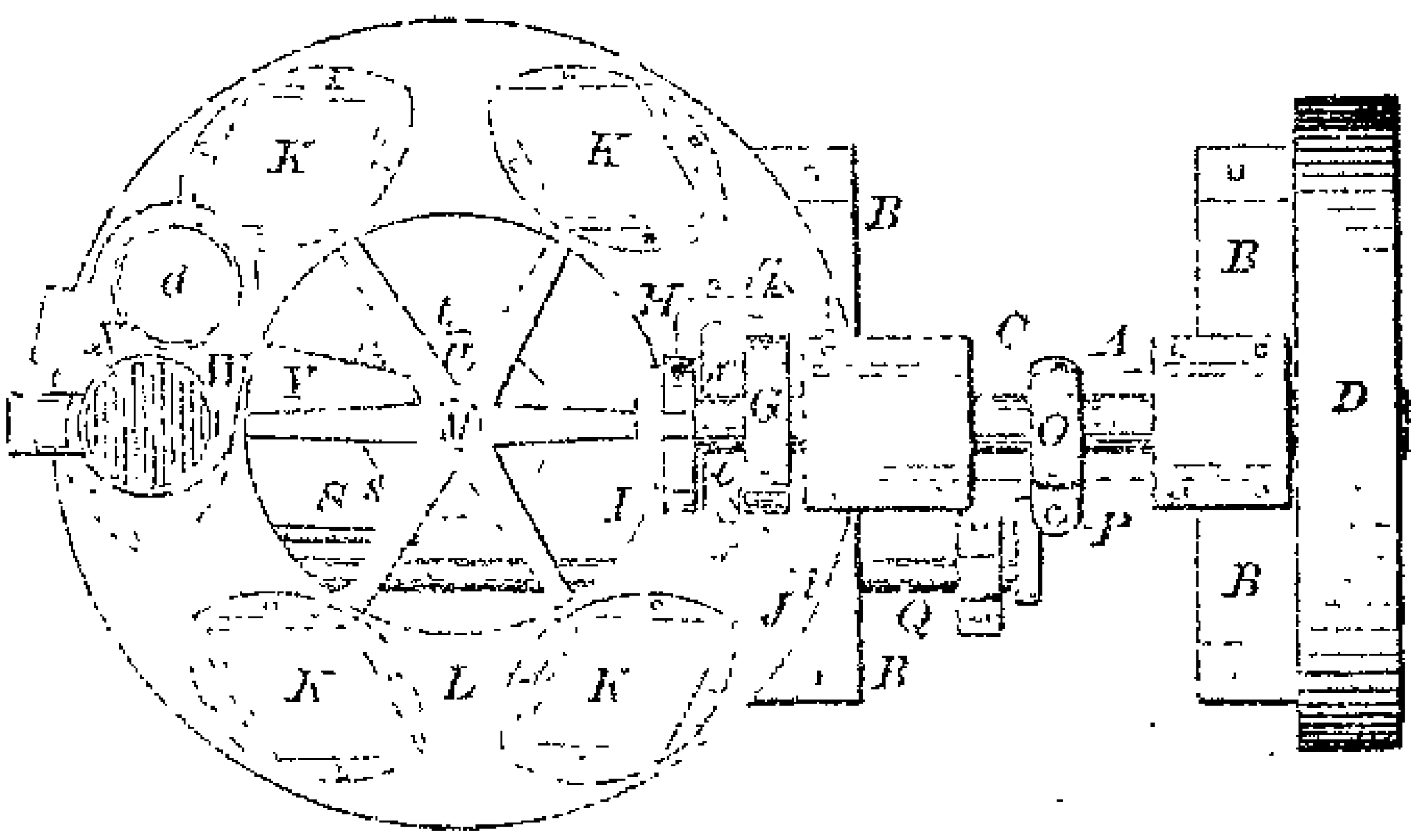
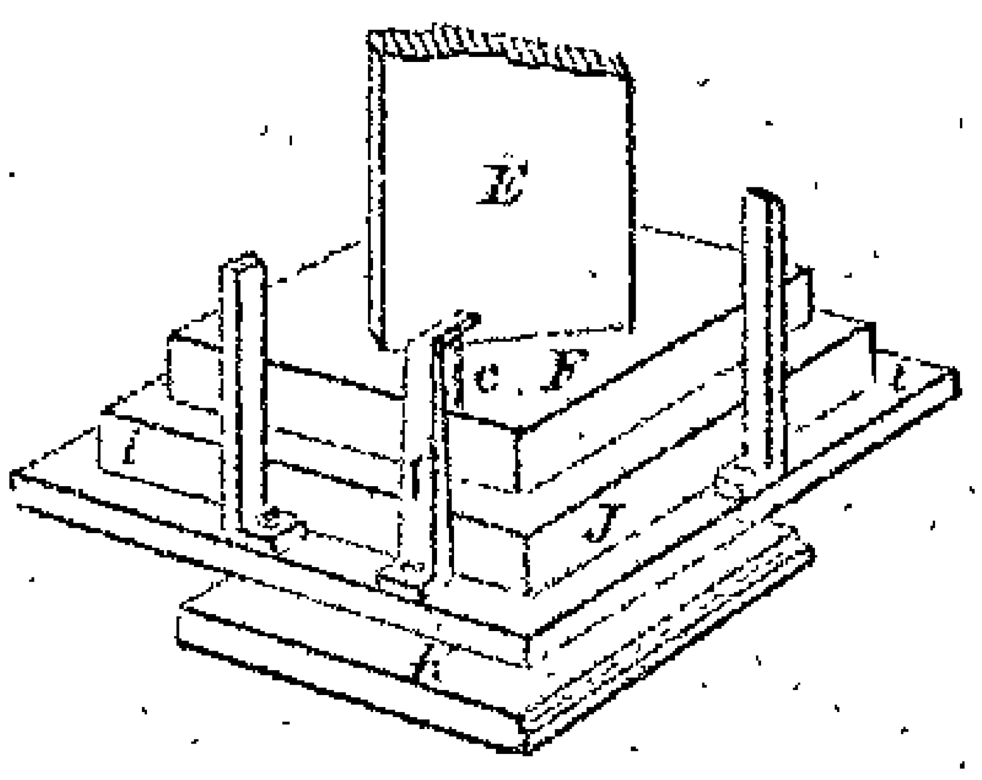


FIG. 252.



the platform *L*, sufficient to bring one of the dies *K* in position beneath the upper die and shell.

In operation, one of the lower dies *K* being in position beneath the upper die, with a portion of clay thereon, by the

action of the cams *I* and *G*, the shell *J* first descends and surrounds the die *K*, to which it is accurately fitted. The upper die then descends within the shell and presses the clay into the desired shape, all excess of clay escaping through the holes *i i* in the ends of the shell *J*. The upper die still remaining on the clay, the shell *J* first ascends; the upper die *F* then ascends; a partial revolution of the platform then ensues, and the operation is repeated.

Especial attention is called to the arrangement of the lower die, shell, and upper die, and the relative motion of the latter two at the time of forming the tile. The upper die at no time entirely leaves the interior of the shell *J*. When the shell *J* descends upon the die *K*, the three parts form a closed mould, with the unpressed clay therein.

By causing the shell *J* to rise first, it cuts off two streams of surplus clay at the holes *i i*, leaving the edges of the tile smooth and clean cut, and permits the upper die to ascend without tearing the green tile, which could not be done if the shell *J* remained down.

In practice it is found that, with every precaution to prevent it, there are always incorporated in the pressed tile particles of compressed air, which, by its expansive force, would, if the die *F* remained at its extreme pressure when the shell *J* was removed, force the clay out laterally between the upper and lower dies, thereby destroying the line and smoothness of the edge of the tile. This is avoided by using an eccentric-cam *G*, to operate the upper die, whereby the upper die begins slowly to ascend the instant after its extreme pressure, thereby permitting the clay to expand upward by the time the shell ascends above it.

Nail-holes are made in the tile as follows: Upon the shell *J* are two standards *V V*, the upper angle whereof is so high as not to interfere with the greatest separation of the upper die and shell. Projecting downward from the top of these are pins *c c*, which pass through holes in the upper die, and of such length that their lower ends shall rest against the face of the

lower die *K* when the shell *J* is at its extreme downward stroke. Their operation will be readily understood from the foregoing description of the press as they follow the motion of the shell *J*.

The feeding device consists of a hollow, open cylinder *W*, supported over one of the lower dies when the latter is at rest, as shown.

Across the bottom of this cylinder slides a plate *X*, supported by an arm *Y*, which swings horizontally on the shaft *M*. In this plate is a depression *d*, as large as the interior circumference of the cylinder *W*, the side of said depression toward the centre of the plate being open, and the edge of the plate at that opening sharpened to form a knife. This plate is caused to oscillate across the lower end of the cylinder *W*, by a pitman attached to the crank-arm *S*.

In operation, a roll of tempered clay is placed in the cylinder. By the action of the arm *S*, in revolving the platform *L*, the depresssion in the plate *X* is brought beneath the cylinder, and into this the roll of clay settles, when, by the return of the plate, a slice of clay is cut off, and falls on the die below.

FIG. 253.

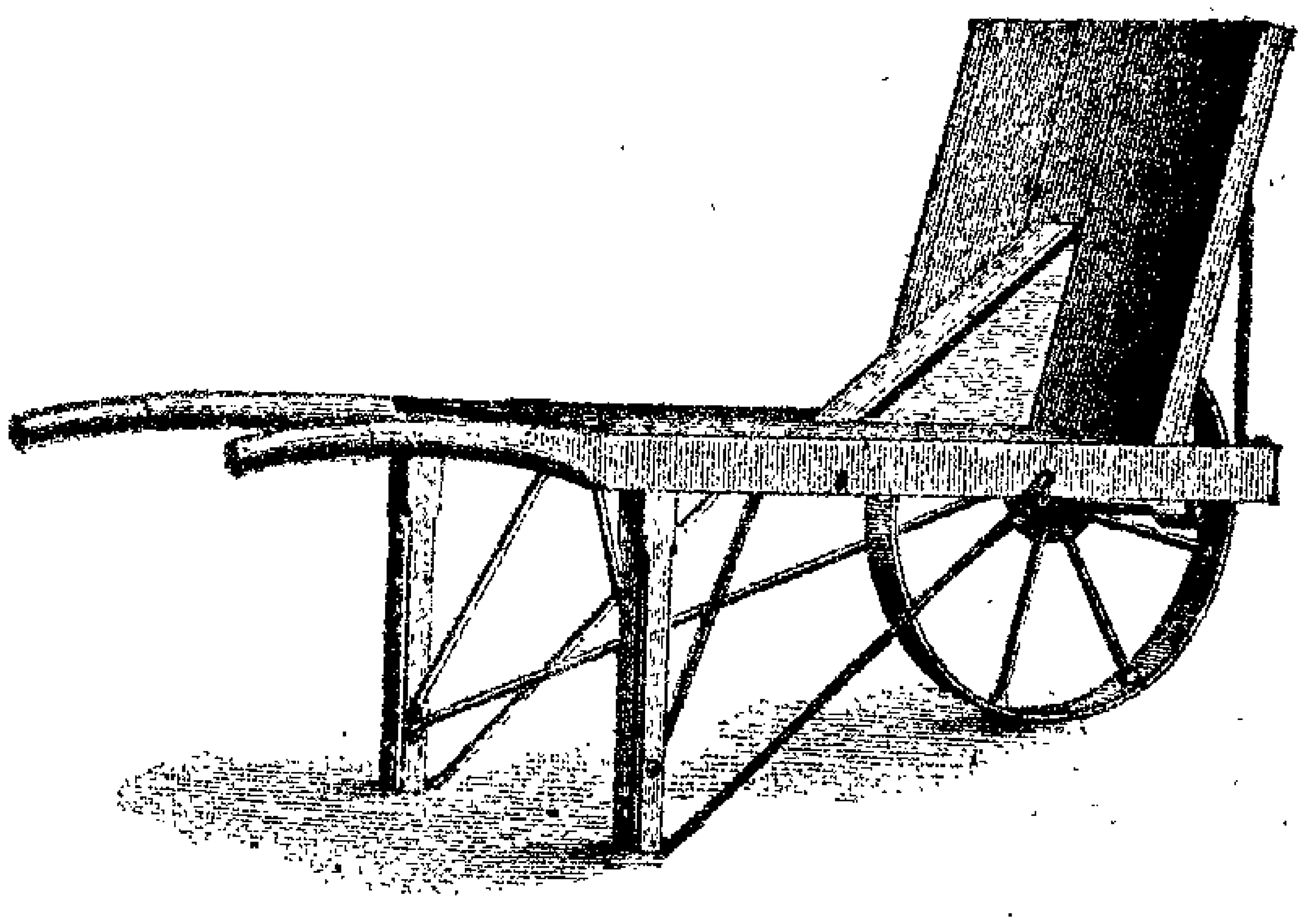
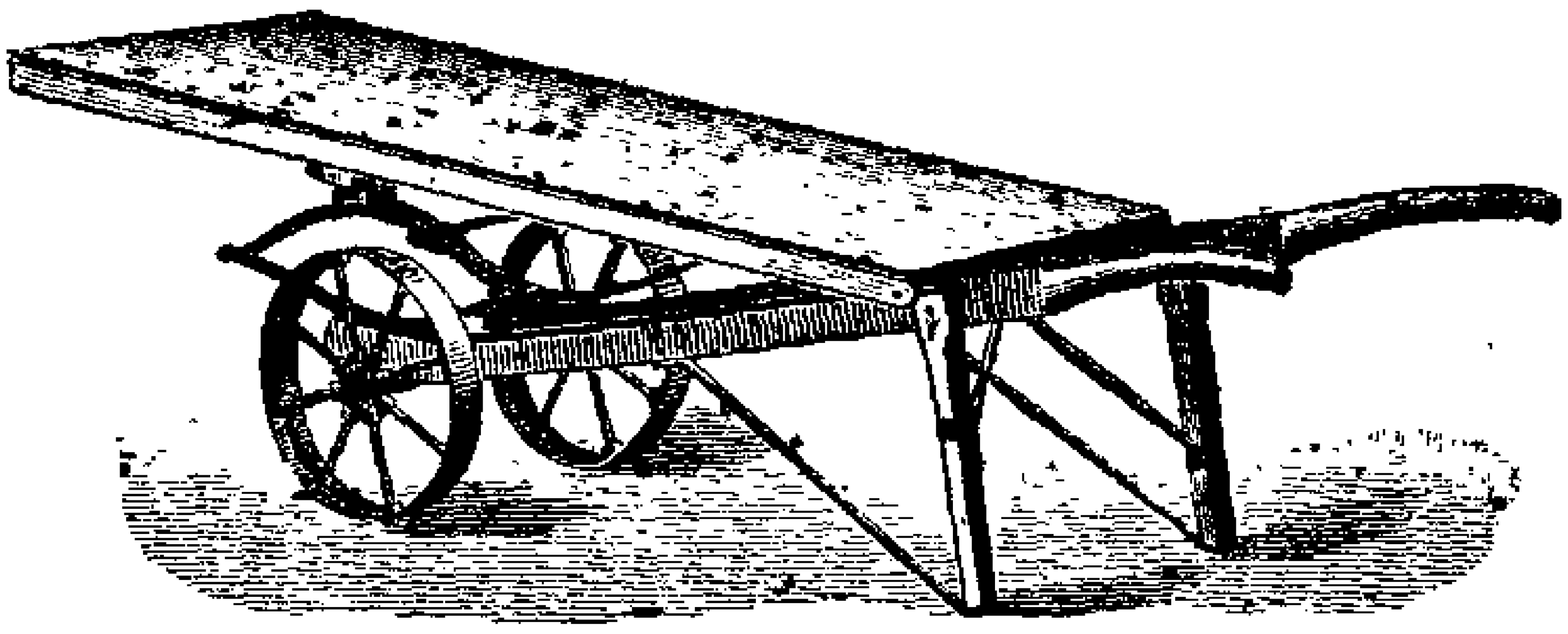


Fig. 253 shows the common form of tile-barrows, which are similar to the brick-barrows, with the exception that they are

wider at the front, the back or "dash" is higher, and the wheel is covered. Fig. 254 shows the form of a tile-truck designed to

FIG. 254.



carry tiles from the machine to the drying-sheds; the usual size of the platform is 28x72 inches, and being mounted on two wheels is not easily upset.

CHAPTER XVII.

THE MANUFACTURE OF MOSAICS AND IMITATION INLAID OR INTARSIA SURFACES.

THIS beautiful method of cementing various kinds of stones, glass, etc., seems to have originated in Persia, whence it found its way into Greece in the time of Alexander, and into Rome about 170 B. C. The critics are divided as to the origin and reason of the name. Some derive it from mosaicum, a corruption of musaicum, or, as it was called among the Romans, musivum. Scaliger derives it from the Greek Morisa, and imagines the name was given to this sort of work by reason of its ingenuity and exquisite delicacy. Nebricensis is of the opinion it was so called because "ex illis picturis ornabantur musea." Mosaic work of glass is used principally for the ornamentation and decoration of sacred edifices. Some of the finest specimens of this work are to be seen in the Church of the Invalides at Paris, in which is the tomb of Napoleon I., and in the fine chapel at Versailles. Mosaic work in marble is used for pavements of churches, basilicas and palaces; and in the incrustation and veneering of the walls of the same structures. As for that of precious stones, it seems to be used only for ornaments for altar pieces and tables for rich cabinets.

The mosaic manufacture at the present day in Rome is one of the most extensive and profitable of the fine arts. Workmen are constantly employed in copying paintings for altar pieces, though the works of the first masters are fast moldering away on the walls of forgotten churches. The French, at Milan, appear to have set the example by copying in mosaic the "Lord's Supper" of Leonardo da Vinci; but their plan was to do much for Milan and nothing for Rome, and consequently a great many invaluable frescoes of Michael

Angelo, Raphael, Domenichino and Guido were left to perish. It takes about seven or eight years to finish a mosaic copy of a painting of the ordinary historical size, two men being constantly occupied in the work. The time and expense are, of course, regulated by the intricacy of the subject and quantity of the work. Raphael's "Transfiguration" took nine years to complete, ten men constantly working at it.

The execution of some of the latter's work is, however, considered very inferior. The slab upon which the mosaic is made is generally of travertin (or tiburtin) stones, connected together by iron clamps. Upon the surface of this a mastic, or cementing paste, is gradually spread, as the progress of the work requires it, which forms the adhesive ground, or bed, upon which the mosaic is laid. The mastic is composed of fine lime from burnt marble, and finely powdered travertin stone, mixed to the consistence of a paste with linseed oil, Into this paste are fixed the "smalts," of which the mosaic picture is formed. They are a mixed species of opaque, vitrified glass, partaking of the nature of stone and glass, and composed of a variety of minerals and materials, colored for the most part with different metallic oxides.

Of these, no fewer than 1,700 different shades are in use. They are manufactured in Rome, in the form of long slender rods, like wires, of various degrees of thickness, and are cut into pieces of the requisite sizes, from the smallest pin point to an inch. When the picture is completely finished, and the cement thoroughly dried, it is highly polished. Mosaic, though an ancient art, is not merely a revived, but an improved one. The Romans only used colored marbles at first, or natural stones, in its composition, whfch admitted of little variety: but the invention of "smalts" has given it a wider range, and made the imitation of painting far closer. The mosaic work at Florence is totally different from this, being merely inlaying in "pietre dure," or natural ornamental or precious stones, of every variety, which form beautiful and very costly imitations of shells, flowers, figures, etc., but bears no similitude to painting.

Inventions are now being developed by which mosaics can be cheaply worked, which, of course, while the work does not compare in merit to that of Italy and Russia, is at the same time suitable for many purposes of domestic ornamentation.

The contrivance shown in Figs. 255 to 258 is the invention of Mr. Robert Eltzner, of New York City, and is for the manufacture of mosaic plates for pavements, wall ornamentation,

FIG. 256.

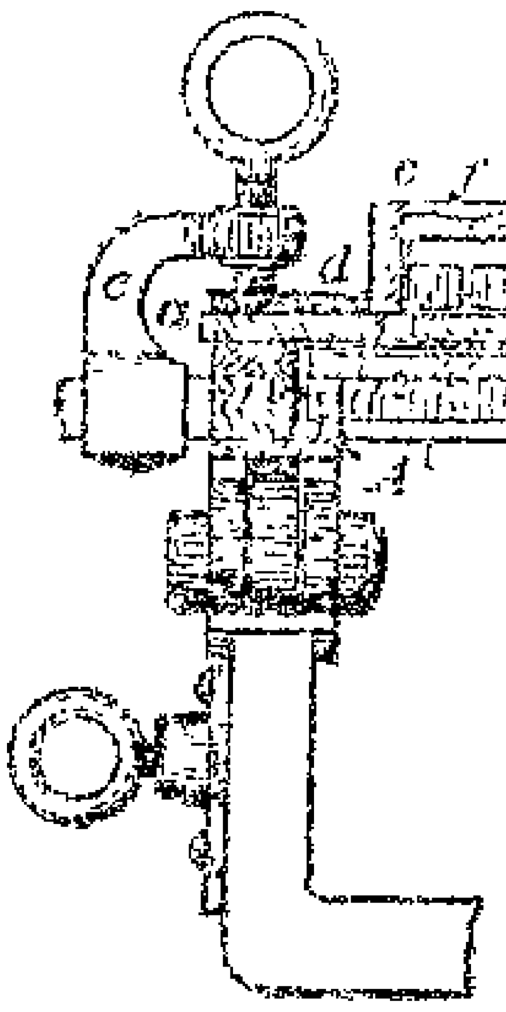


FIG. 257.

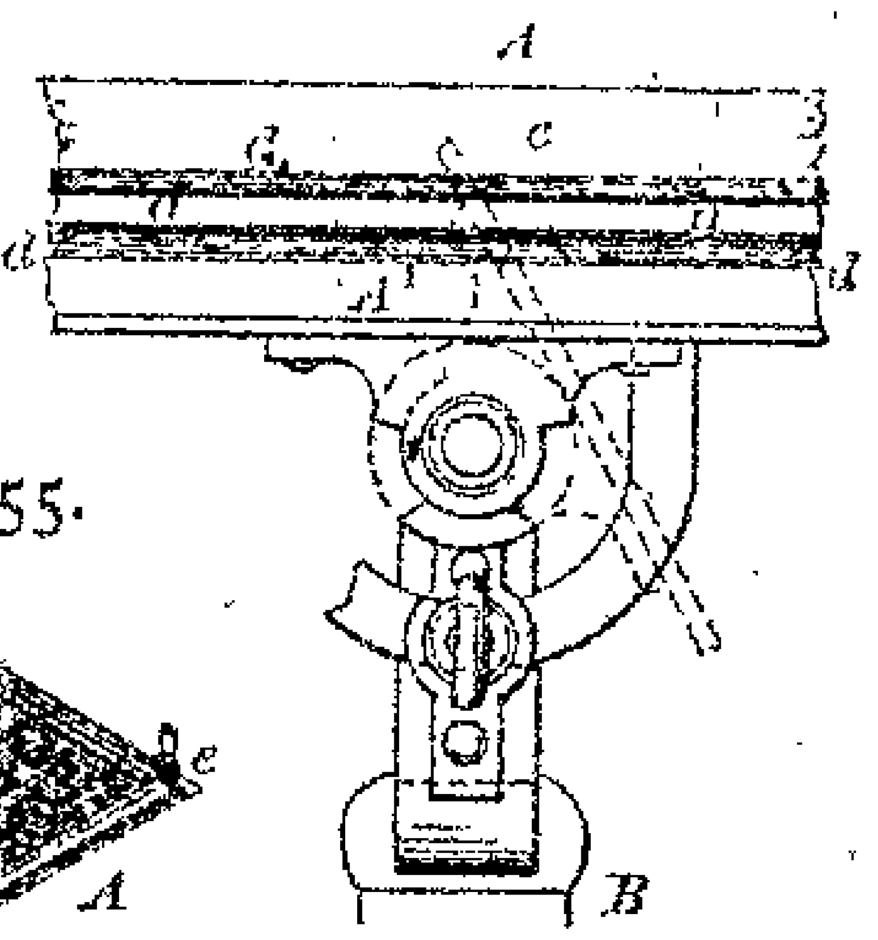


FIG. 255.

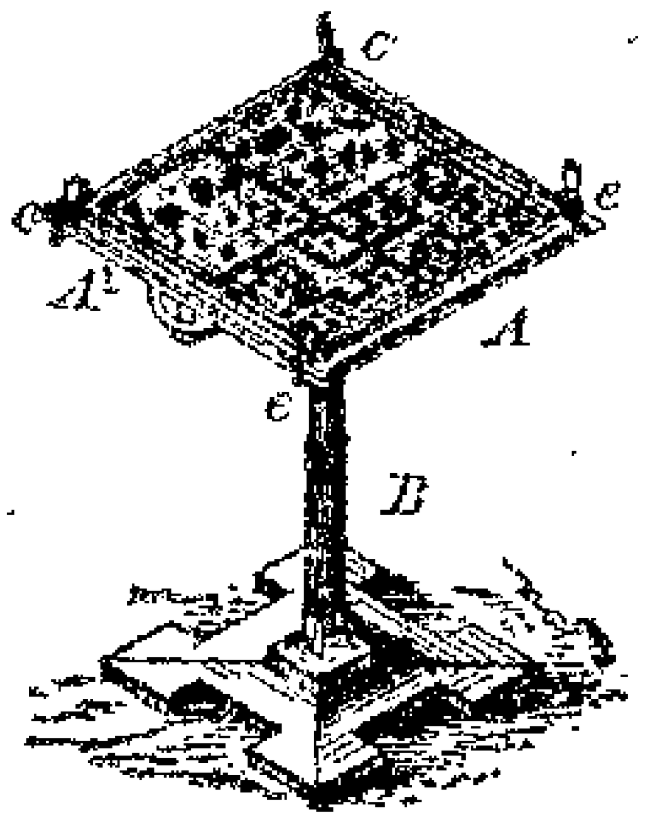
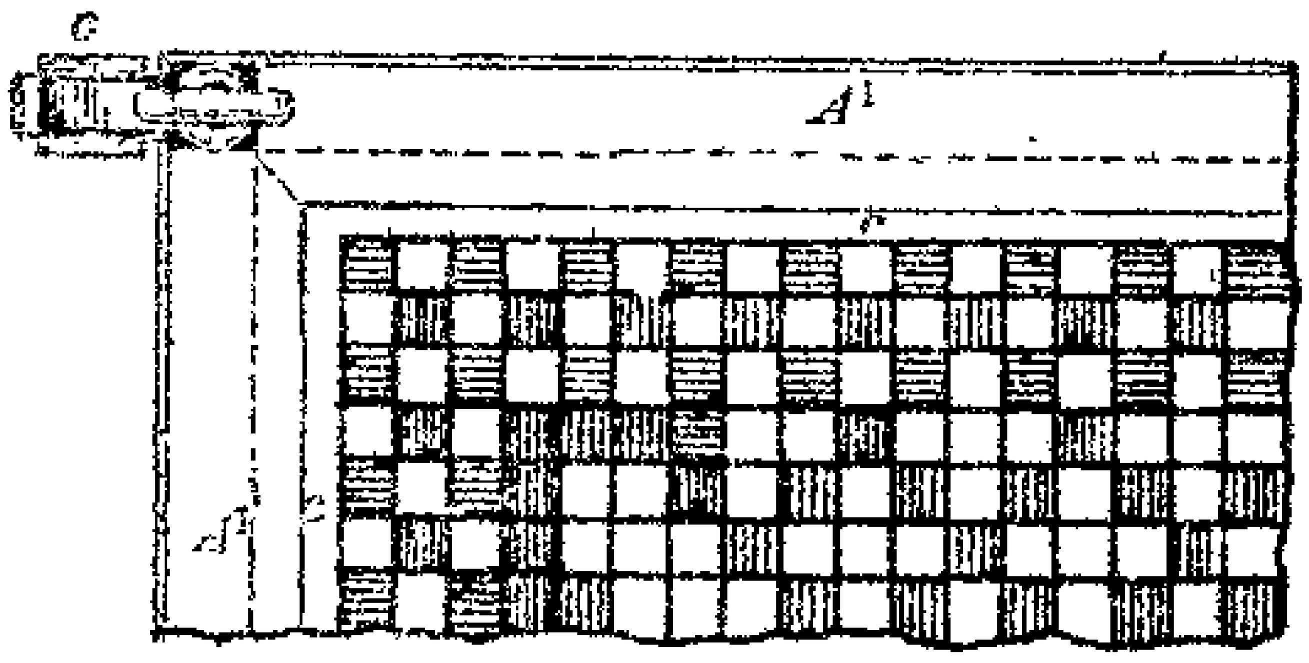


FIG. 258.



furniture, and other decorative purposes from natural and artificial material, such as marble, slate, porcelain, majolica, glass, jet, wood, and the like, so that any desired design can be produced without the employment of especially skilled hands, and thus very ornamental articles be furnished at reasonable prices for application in the arts.

The invention consists of a mosaic tablet or plate, the indi-

vidual blocks of which are arranged face downward, according to a pattern or design on transparent paper that has been placed between two glass plates, so that light can fall through from below. The blocks of mosaic which form the plate are finally backed by means of a cement, leaving open joints, and stiffened with and exterior strip or band, as will appear more fully hereafter.

Fig. 255, represents a perspective view of the table on which the mosaic plate is formed. Fig. 256 is a detail vertical transverse section of the same. Fig. 257 is a detail side view of a portion of the table, both figures being drawn on an enlarged scale, and Fig. 258 is a plan view of a mosaic plate formed on a table.

In carrying out the invention, a table *A*, of the size of the mosaic plate to be formed, is supported on a suitable stand *B*. The table *A* is made of an exterior iron frame A^1, and of two glass plates *a* and *b*, between which is placed the drawing of the design which is to be produced in mosaic. The design is made on transparent or translucent tracing-paper, which is placed between the two glass plates with the face side downward, and secured by gum to the lower glass plate *b*. The thickness of the covering glass plate *a* increases with the size, weight, and thickness of the mosaic tablet to be produced. Upon the top glass plate *a*, a rectangular frame of upright glass strips *c* is placed, the corners of which are held together by stout paper strips pasted thereto. Below the glass strips *c* is placed a layer of paper, which covers the glass plate *a* outside of the glass strips *c*, so as to protect the surface of the former. Outside of the vertical glass strips *c* are arranged flat rubber strips *d*, also intermediate rubber strips d^1, d^2 between the glass plates *a b* and frame A^1, the rubber strips d^1, d^2, and the clamps *e*, which are applied near the corners of the frame A^1, holding the glass plates firmly in position upon the iron frame of the table. The vertical glass strips *c* vary in height according to the thickness of the mosaic plates to be formed, and serve as the exterior walls for the cement backing which is given to the

mosaic plate. A strip or band *f*, of galvanized wire-gauze, is placed in position along the inner surface of the glass strips, as shown in dotted lines in Fig. 256. The band *f* should not extend lower down than the depth of the joint between the blocks of the plates, for which purpose, so as to obtain the correct position of the band *f*, a flanged zinc strip f^1 is placed upon the glass plate *a*, below the rubber strips *d*, the zinc strips extending below the glass strips *c c* to the inside, its flange projecting upward along their inner surface for supporting the band *f*, as shown in Fig. 256. The individual blocks of mosaic, whatever be the material employed, are now placed in position upon the covering glass plate *a*, according to the design represented on the tracing-paper between the plates *b a*. As the light passes through the glass plates from below, it renders the configuration and colors of the design clearly visible, so that the exact position and color of the blocks required are clearly recognized. One row after the other, from the left to the right, is successively placed in position, the faces of the blocks being gummed, so that they adhere to the glass plate. If it be desired to bring out some portions of the design in relief, the remaining portions have to be covered with square glass plates of the size of the block, so that the blocks placed thereon are set somewhat below the blocks without glass plates. When all the blocks are placed in position according to the design, the covering plate *a*, with the blocks remaining thereon, face downwards, is removed from the frame for being backed and finished, while the table itself is ready for forming the next mosaic plate. For finishing the mosaic plate, the open joints between the blocks are now partly filled up with a layer of fine sand to the depth of the joints. As soon as this is done, a backing *g*, of a proper cement, plaster-of-paris, or other suitable material, is spread into the joints and over the back of the blocks until they are covered to the thickness of one-eighth to one-quarter of an inch. A layer g^1 of wire-gauze is placed upon the cement and imbedded therein, after which it is covered with a thick layer of cement, plaster-of-paris, or other material, to which,

according to the thickness of the plate, sand or small lumps of stone are added. As soon as the cement backing has sufficiently set, the clamping-screws are unscrewed, the paper strips at the corners of the glass strips *c* cut through, and the latter removed. The mosaic plate is then lifted off from the glass plate *a*, and placed face upward on a suitable setting-plate for final drying. The joints are then cleared of the adhering sand by means of a brush, and the mosaic plate is finished.

If desired, the blocks may be connected in a still more reliable manner by means of short metallic strips, which are cast in by the cement between the blocks, or by other means, as wished. In this connection it may be mentioned that the proper size of the working-table to be used is preferably equal to four square feet, so that four mosaic plates each one square foot in size may be made at the same time, the separation of the plates being readily obtained by means of a dividing-cross of glass strips. If larger mosaic plates are desired, larger working-tables may be used. The frame of the table is preferably connected to the supporting stand by means of a hinged joint and semicircular guide-rails, so as to be set into into inclined position, by which the passage of the light through the design is facilitated. If extra large and heavy mosaic plates *h* are to be made, the lower glass plate *b* is made of several pieces, between which iron stiffening-rails are interposed.

The advantages of this improved method of manufacturing mosaic plates are that any desired design may be quickly produced without the employment of skilled hands, and that a number of persons can be employed at the same time to produce different plates. The plates can be made by daylight or artificial light, provided the colors on the design can be properly distinguished. As the joints between the blocks are open, a secure foothold is furnished when used for pavement. The plates do not require to be made of any great thickness, as the inclosing band and interposed layer of wire gauze in the backing impart to them considerable strength and thickness.

IMITATION INLAID OR INTARSIA SURFACES.

The invention shown in Figs. 259 to 261 relates to the production, as distinctve articles of manufacture, of tiles, table-tops, wainscoting, panels, work-boxes, articles of furniture of all kinds, and fancy or ornamental articles generally.

A mould or matrix is first prepared, of metal, slate, or any fit material, and of suitable size and construction, in the bottom of which, or in the bottom and sides of which, the outlines of the ornament or ornaments with which the finished article is to be embellished are depressed, sunk, engraved, or intagliated. Into the mould or matrix thus prepared is placed the material, compound, or composition which is to form the base of the manufactured article. If this is to be an ornamental plaque or a tile, for example, clay, plaster-of-paris, or any artificial stone compound may be used, which is pressed into the mould, so that the intagliated lines in this will appear upon the plaque or tile, when this is withdrawn from the mould, as outlines of relief.

Almost any material, compound, or composition is capable of being used with and ornamented by this process, such as plastic materials or compounds, stone, wood, cast metal, or any sheet metal or metallic foil, such materials as are not themselves capable, on account of hardness, of receiving an impression in the mould or matrix being first covered or coated with a compound of a soft or plastic nature. Wood, by being steamed, boiled, or treated in several other well-known ways, is adapted for ornamentation by this process, either plain or veneered, and with or without a plastic coating of varnish, shellac, or any suitable paint composition.

Fig. 259 is a plain view of a plaque or panel with an imitation-intarsia surface. Fig. 260 is a section of the mould or matrix; and Fig. 261 is a similar section, showing a modification in the construction of the mould or matrix.

In the treatment of some materials it is desirable to construct the matrix in the shape of rollers, one of which has a flat surface, and the other is provided with indented or engraved lines, which will form the outlines in relief upon the material passed

between them. When a hollow mould or *matrix* is used, this may be constructed as represented in Fig. 261, that is, with a raised or depressed part *a*, forming either a shoulder, as indicated by the full line, or a recess as indicated by the dotted lines, at each end of said figure, which shoulder or recess, as the case may be, surrounds the engraved or intagliated bed of the mould, by which the ground or real surface of the article or material to be ornamented will be exposed in its natural state. By either of these methods a base may be used, which consists

Fig. 259.

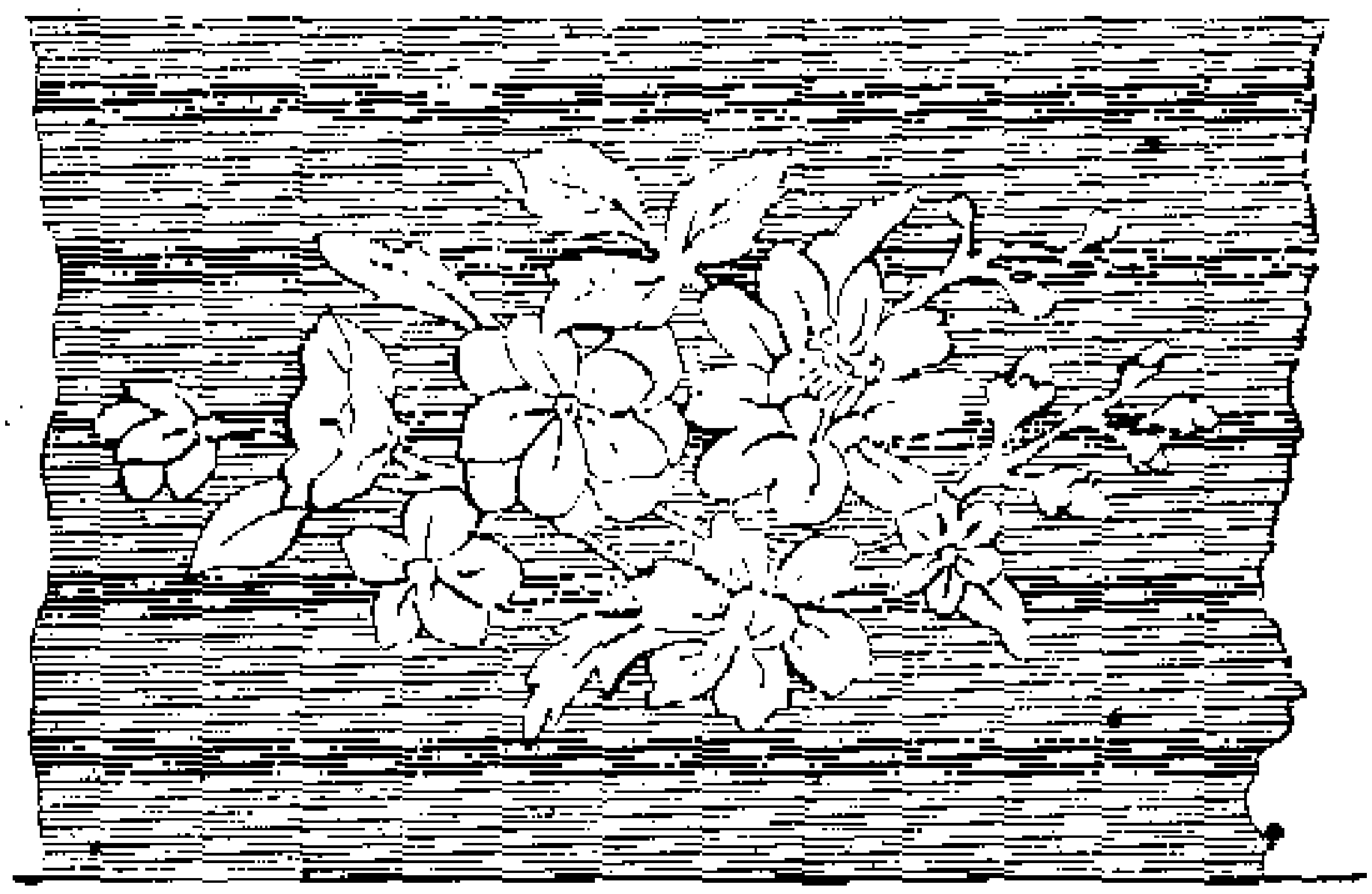


Fig. 260.

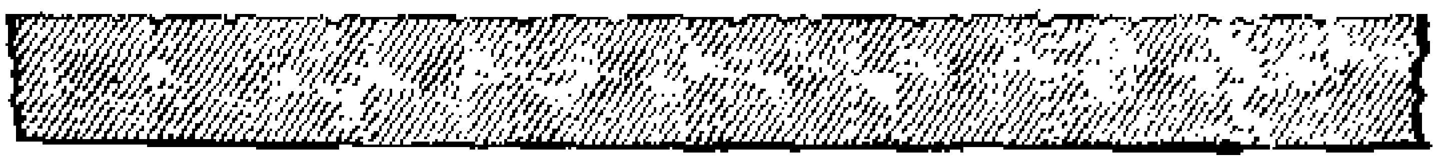


Fig. 261.

of several parts or layers, which allows of an endless combination and variety of materials adapted to be used by this process in the production of imitation-intarsia articles of manufacture, or articles of any kind ornamented by this process.

After the base has been produced with lines in relief in the manner described, and the spaces within the lines filled in with enamel, paint, or any suitable colored composition, and the surface rubbed down smooth, and varnished, if desired, as fully set

forth, the article so prepared, if of clay, and ornamented with mineral colors or enamel, is baked to give it the requisite degree of hardness and durability, and bring out the colors. The subsequent treatment of the ornamented articles will, of course, differ according to their nature and the purposes for which they are intended; but the process of producing the raised outlines and subsequent filling in with coloring matter, is in all cases substantially the same.

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